Breast pain and breast injuries experienced by female athletes

Brooke R. Brisbine
_University of Wollongong_

Follow this and additional works at: https://ro.uow.edu.au/theses1

University of Wollongong
Copyright Warning
You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site.

You are reminded of the following: This work is copyright. Apart from any use permitted under the Copyright Act 1968, no part of this work may be reproduced by any process, nor may any other exclusive right be exercised, without the permission of the author. Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material. Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

Unless otherwise indicated, the views expressed in this thesis are those of the author and do not necessarily represent the views of the University of Wollongong.

Recommended Citation

Research Online is the open access institutional repository for the University of Wollongong. For further information contact the UOW Library: research-pubs@uow.edu.au
BREAST PAIN AND BREAST INJURIES EXPERIENCED BY FEMALE ATHLETES

Brooke R. Brisbane
Bachelor of Medical and Health Sciences

Supervisors:
Dr Deirdre E. McGhee
Senior Professor Julie R. Steele
Dr Elissa J. Phillips

This thesis is presented as part of the requirements for the conferral of the degree of

Doctor of Philosophy

This research has been conducted with the support of the Australian Institute of Sport

School of Medicine
Faculty of Science, Medicine and Health
University of Wollongong

December 2019
DEDICATION

This thesis is dedicated to all the female athletes who have felt somehow limited by their breasts.

To acknowledge the unique anatomy of female athletes isn’t to “sexualise the game” or provide evidence of inferiority; it’s to legitimise the pain and injuries that many women experience during training and competition and to normalise conversations in the sporting community about how these challenges can be overcome. There is strength in refusing to “just deal with it” and instead working towards evidence-based management and prevention strategies that will allow female athletes to compete at their best. Hopefully, this thesis is just the beginning.
## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of tables</td>
<td>vii</td>
</tr>
<tr>
<td>List of figures</td>
<td>ix</td>
</tr>
<tr>
<td>Publications</td>
<td>xi</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>xii</td>
</tr>
<tr>
<td>Abstract</td>
<td>xiv</td>
</tr>
<tr>
<td>Chapter 1: The problem</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Introduction</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Aim</td>
<td>13</td>
</tr>
<tr>
<td>1.3 Significance of the thesis</td>
<td>14</td>
</tr>
<tr>
<td>Part I: Breast pain in elite female athletes</td>
<td>17</td>
</tr>
<tr>
<td>Chapter 2: Breast pain affects the performance of elite female athletes</td>
<td>18</td>
</tr>
<tr>
<td>2.1 Introduction</td>
<td>19</td>
</tr>
<tr>
<td>2.2 Design and methods</td>
<td>21</td>
</tr>
<tr>
<td>2.3 Results</td>
<td>25</td>
</tr>
<tr>
<td>2.4 Discussion</td>
<td>30</td>
</tr>
<tr>
<td>2.5 Conclusion</td>
<td>33</td>
</tr>
<tr>
<td>Chapter 3: Can physical characteristics and sports bra use predict</td>
<td>35</td>
</tr>
<tr>
<td>exercise-induced breast pain in elite female athletes</td>
<td></td>
</tr>
<tr>
<td>3.1 Introduction</td>
<td>36</td>
</tr>
<tr>
<td>3.2 Design and methods</td>
<td>39</td>
</tr>
<tr>
<td>3.3 Results</td>
<td>42</td>
</tr>
<tr>
<td>3.4 Discussion</td>
<td>44</td>
</tr>
<tr>
<td>3.5 Conclusion</td>
<td>48</td>
</tr>
</tbody>
</table>
Chapter 8: Summary and recommendations ............................................. 134
  8.1 Summary .................................................................................. 134
  8.2 Recommendations for future research ....................................... 139
  8.3 Recommendations for sports to manage breast pain and breast injury ...... 142

References ............................................................................................... 144

Appendices ............................................................................................... 160
  Appendix A: International bra sizing ................................................. 160
  Appendix B: Breast pain and breast injury survey ........................... 161
  Appendix C: Contact breast injury survey ........................................ 175
  Appendix D: Staff survey ................................................................. 179
  Appendix E: Breast injury fact sheet ................................................ 180
Table 1: Characteristics of the 540 elite female athletes who completed the survey compared to physical characteristics of a sample of Australian women from the general population ................................................................. 26

Table 2: The total number of responses and the frequency count of participants reporting exercise-induced breast pain at each of 5 points on the scale (from very severe, score = 1 to no breast pain, score = 5). All responses were averaged to report an overall mean severity for each activity and scores 1–4 (“yes” breast pain) were counted and divided by the total number of responses to represent the percentage of participants who experienced exercise-induced breast pain during each activity (occurrence) ............................................................................................................. 28

Table 3: Mean difference of the reported severity of exercise-induced breast pain (rated on a 5-point Likert scale) between nine sport-related activities......... 29

Table 4: Australian bra sizes grouped into four breast size categories based on approximate breast volume: 1 = small breasts (<350 ml); 2 = medium breasts (350–700 ml); 3 = large breasts (701–1200 ml); and 4 = hypertrophic breasts (>1200 ml)...................................................................................................................................... 40

Table 5: Mean ± standard deviation (and minimum, maximum) values of characteristics for the participants who reported exercise-induced breast pain, participants who did not report exercise-induced breast pain and all participants......................................................................................................................................... 43

Table 6: Results of the binomial logistic regression that used age, breast size, BMI and frequency of sports bra use to predict the likelihood of a participant reporting exercise-induced breast pain ...................................................... 43

Table 7: Percentage of participants from non-contact sports and contact/combat sports who reported contact breast injuries, frictional breast injuries and any breast injuries .......................................................................................................................... 60
Table 8: Number and percentage of participants who perceived negative performance effects as a result of their contact breast injuries (n = 82)...... 80

Table 9: Percentage of participants from each player position within AFL and within all Rugby codes (League, Union, 7s) who reported sustaining any contact breast injury, a contact breast injury caused by another player, the ball or the ground and negative performance effects as the result of their contact breast injury ......................................................... 82

Table 10: Number of staff who responded to the survey from each football code ...... 83

Table 11: Number of staff who responded to the survey, classified by staff role........ 83

Table 12: The bra fit criteria used to assess the fit of each athlete’s bra(s)............. 98

Table 13: Reasons given by participants (n = 150) for not using breast or chest protective equipment during training and matches................................................. 102

Table 14: A description of how the breast size, breast position and torso size of each participant was directly measured or calculated, with the corresponding figures noted. ................................................................. 117

Table 15: Mean (± standard deviation) age, height, body mass and body fat percentage values for the participants by contact football code............. 121

Table 16: Relevant breast padding or protective equipment regulations within each of the contact football codes................................................................. 132
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Figure 1:</strong></td>
<td>The Team-sport Injury Prevention framework (O’Brien et al. 2019)</td>
<td>12</td>
</tr>
<tr>
<td><strong>Figure 2:</strong></td>
<td>Schematic representation of the thesis structure and how each part contributes to the overall thesis aim.</td>
<td>16</td>
</tr>
<tr>
<td><strong>Figure 3:</strong></td>
<td>Percentage of participants with “small breasts” and with “medium to hypertrophic breasts” who did report or did not report exercise-induced breast pain</td>
<td>44</td>
</tr>
<tr>
<td><strong>Figure 4:</strong></td>
<td>The percentage of participants competing: (A) in contact/combat sports or non-contact sports and (B) in national or international competitions</td>
<td>59</td>
</tr>
<tr>
<td><strong>Figure 5:</strong></td>
<td>The frequency distribution of (A) age, (B) breast size, (C) BMI, (D) frequency of sports bra use, and (E) weekly training for participants who did and did not report contact breast injuries</td>
<td>61</td>
</tr>
<tr>
<td><strong>Figure 6:</strong></td>
<td>The frequency distribution of (A) age, (B) breast size, (C) BMI, (D) frequency of sports bra use, and (E) weekly training for participants who did and did not report frictional breast injuries</td>
<td>62</td>
</tr>
<tr>
<td><strong>Figure 7:</strong></td>
<td>The percentage of player participants (n = 297) representing each (A) football code, (B) player position, and (C) competition level</td>
<td>79</td>
</tr>
<tr>
<td><strong>Figure 8:</strong></td>
<td>Percentage of participants from each football code who reported sustaining any contact breast injury, a contact breast injury caused by another player, the ball or the ground and negative performance effects as the result of their contact breast injury</td>
<td>81</td>
</tr>
<tr>
<td><strong>Figure 9:</strong></td>
<td>Percentage of participants from each competition level who reported sustaining any contact breast injury, a contact breast injury caused by another player, the ball or the ground and negative performance effects as the result of their contact breast injury</td>
<td>82</td>
</tr>
<tr>
<td><strong>Figure 10:</strong></td>
<td>Frequency distribution of the occurrence of contact breast injuries estimated by the staff respondents (n = 242)</td>
<td>83</td>
</tr>
<tr>
<td><strong>Figure 11:</strong></td>
<td>Types of breast support</td>
<td>98</td>
</tr>
</tbody>
</table>
Figure 12: Flow of participants through the present study .................................................. 101

Figure 13: Participants (n = 207) from each contact football code who reported using breast padding, shoulder pads with chest pads or no padding during training and matches ............................................................................................................ 102

Figure 14: Number of participants (n = 112) whose bra cups were measured to have no padding, low padding, medium padding or high padding on the superior and inferior bra cups ......................................................................................................................... 104

Figure 15: Participants were scanned while holding the handles of a turntable that was slowly rotated (primary scan position; A). Participants whose level of breast ptosis prevented complete visualisation of their inferior breast were scanned while they held their hands on their head (secondary scan position; B) .......................................................................................................................... 115

Figure 16: Screenshots of an example of the steps taken to calculate the breast and torso measurements using Geomagic® software .......................................................... 119

Figure 17: Box plots depicting the median and interquartile range of the breast size measurements (A)–(F) by contact football code .................................................. 122

Figure 18: Box plots depicting the median and interquartile range of the breast position measurements (A)–(D) by contact football code ......................... 123

Figure 19: Box plots depicting the median and interquartile range of the torso size measurements (A)–(C) by contact football code .................. 124
This thesis includes chapters that have been written as the following journal articles:


**Chapter 6:** Brisbine BR, Steele JR, Phillips EJ and McGhee DE. Use and perception of breast protective equipment by female contact football players. *Journal of Science and Medicine in Sport.* 2020. doi:10.1016/j.jsams.2020.02.004

**Chapter 7:** Brisbine BR, Steele JR, Phillips EJ and McGhee DE. Breast and torso characteristics of female contact football players: Implications for the design of sports bras and breast protective equipment. *Ergonomics.* 2020. doi:10.1080/00140139.2020.1757161

As the primary supervisor, I, Dr Deirdre E. McGhee, declare that the greater part of the work in each article listed above is attributed to the candidate, Brooke R. Brisbine. In each of the above manuscripts, Brooke contributed to the study design, recruited participants, was solely responsible for data collection and data analysis, and was largely responsible for statistical analysis and data interpretation. The first draft of each manuscript was written by the candidate, who was then responsible for responding to the editing suggestions of her co-authors. Deirdre McGhee, Julie Steele and Elissa Phillips, were responsible for assisting in study design, data interpretation and editing the manuscripts. Brooke was responsible for submitting each manuscript for publication to the relevant journals and assisted her co-authors in responding to reviewer’s comments.

Brooke R. Brisbine  
17 December 2019  
Deirdre E. McGhee  
17 December 2019
ACKNOWLEDGEMENTS

I owe an incomprehensible amount of thanks to my UOW supervisors, Associate Professor Deirdre McGhee and Senior Professor Julie Steele, for their unwavering faith in this project, their invaluable expertise and their own passion for breast health biomechanics. I consider myself extremely lucky to have been surrounded and supported by such inspirational women, and I admire you both more than you know.

Deirdre, thank you for inspiring me to care about breast issues as deeply as you do, for your constant words of encouragement and for giving up your nights and weekends to read draft 19 of a paper. Julie, thank you for instilling in me the skills necessary to approach a problem logically and systematically (what is your question!) and for encouraging me to review the evidence and develop my own ideas and opinions, even if they differed from your suggestions.

I must also thank Dr Elissa Phillips, my wonderful industry supervisor from the Australian Institute of Sport (AIS). Thank you for supporting my project from start to finish, for supplying all the sport-specific knowledge I lacked and for being a much-needed force of calm on this team of fiery women.

A further thank you to the AIS for providing funding for this project, as well as all of the athletes, sporting organisations, coaches and medical staff whose support has made it possible. Nearly 1,200 participants were involved across the many stages of this thesis and I owe each and every one of them an enormous amount of gratitude for volunteering their time, and often their breasts, in the name of science.

To my Biomechanics Research Laboratory family, thank you for an unforgettable 3.5 years! I am so lucky to have been part of this wildly diverse yet tight-knit group— you are all incredibly brilliant and passionate people who made my research experience, and also me, better by association. Thanks in particular to Dr Jess Dobson, who supported me through the highs and lows of my candidature with a lot of wisdom and laughter; Maddy Kirk, who was always ready and willing to unleash her formatting prowess on this document; Chris Richards, who was the ultimate tech support; and Dr Celeste Coltman, who was a wonderful mentor in all things breast biomechanics.
An enormous thanks also to Diana Jermann, my wonderful (and very overqualified) research assistant who travelled more than 5,000 km with me for data collection and without whom this project would not have succeeded.

Lastly, thank you to all the friends and family who supported me in a million different ways during my candidature. A special thank you to Ben Peterson, who was always keen to help me in the lab or debrief over lunch; Brooke Duffy and Lucy Absalom, who welcomed me as their third roommate in Canberra whenever I needed to spend time at the AIS; and Doug Field, who taught me just about everything I know when it comes to contact football. Mum, Dad and Eileen, thank you for the emotional support, the fantastic overseas distractions and the constant reminders that you are proud of me, which was often all I needed to hear. And to Callum and Henri, thank you for all that you have sacrificed so that I could pursue this PhD.
ABSTRACT

Background: Due to breast motion experienced during sport and the vulnerability of the female breasts to injury, breast pain and breast injury are potential issues for female athletes across a range of sports. These issues, however, have never been comprehensively investigated in a diverse cohort of elite female athletes, and therefore the extent to which breast pain and breast injuries occur or affect performance is unknown.

Research aim: The overall aim of this thesis was to investigate breast pain and breast injury experienced by female athletes in order to inform future research and provide evidence-based recommendations to manage breast pain and breast injury during sport.

Methods: Two main studies were conducted, which are presented in four thesis parts. An exploratory study was first implemented to investigate breast pain (Part I; Chapters 2 & 3) and breast injury (Part II; Chapter 4) in elite female athletes using a valid and reliable custom-designed survey. Based on the unique findings of Part II of this thesis, a second study was implemented to investigate the current breast injury and breast injury prevention situation in female contact football players, using a custom-designed survey and a physical assessment (Part III; Chapters 5 & 6). Three-dimensional scanning was then used to characterise the breasts and torsos of female contact football players in order to inform the future design of breast protective equipment for female contact football players (Part IV; Chapter 7).

Major conclusion: Based on the results of this thesis, which established that breast pain and breast injury are real issues for elite female athletes and contact football players, several recommendations have been made for future research investigating breast pain and breast injury (Chapter 8). Specifically, continued research on breast injury risk, mechanisms of injury and injury prevention strategies for female contact football players is essential. Evidence-based recommendations have also been made for sports to manage breast pain and breast injury through increased awareness and education amongst athletes, coaches and medical staff.
Chapter 1

The problem

1.1 Introduction

All female breasts consist of the same structural components: glandular tissue, adipose tissue and connective tissue. The percentage composition of these structures, however, varies with factors such as age, menopausal status, parity and body mass index (BMI) (Boyd et al. 2009; Gefen and Dilmoney 2007; Gehlsen and Stoner 1987; Safilas et al. 1991; Torres-Mejia et al. 2005; Vachon et al. 2000). The size and shape of female breasts are also highly variable (Coltman et al. 2018a; Gefen and Dilmoney 2007; McGhee and Steele 2011). In fact, researchers have measured breast volumes ranging from 48–3100 ml in the general female population, with breast volumes greater than 1200 ml considered to be hypertrophic (Coltman et al. 2017b).

Although breast mass can exceed a kilogram (Gehlsen and Stoner 1987; McGhee et al. 2013; Turner and Dujon 2005), breasts have very limited anatomical support. The only anatomical structures that support the breasts are the skin overlying the anterior chest and an internal network of suspensory ligaments, called Cooper’s Ligaments (Chang et al. 2009; Gaskin 2017; Gefen and Dilmoney 2007; Gehlsen and Stoner 1987; Lorentzen and Lawson 1987; Mason et al. 1999). These structures, however, typically do not provide sufficient support to the breasts when women participate in physical activity, and therefore the breasts can move relative to the trunk (Haake and Scurr 2010; Mason et al. 1999; Risius et al. 2015; Scurr et al. 2009).

1.1.1 Breast motion

Breast motion during physical activity was first quantified in the 1970s, when Haycock et al. (1978) used high speed film to monitor the breast motion of women running on a
treadmill. Since this initial biomechanical study, numerous researchers have investigated breast motion while females performed various exercise modalities. According to a systematic review conducted by Zhou et al. (2011), most breast biomechanics researchers have investigated displacement and acceleration of the breasts while women perform short bursts of treadmill running. More recent research has also documented breast motion during over-ground running (Risius et al. 2017; White et al. 2015; White et al. 2011). During cyclic activities, such as walking and running, most breast motion occurs in the vertical direction (Scurr et al. 2011), which accounts for as much as 50% of the total three-dimensional breast motion when women run at high speeds (Scurr et al. 2011). The magnitude of this vertical movement, however, is highly variable, with researchers reporting vertical breast displacements ranging from 0.43–5 cm during walking and 0.93–12 cm during running (Scurr et al. 2009; Zhou et al. 2011; Zhou et al. 2013). A higher magnitude of breast motion during physical activity has been associated with increased breast mass (Haake and Scurr 2010; Lorentzen and Lawson 1987; Wood et al. 2012) and increased movement of the trunk, arms and lower limbs (Chen et al. 2016; Gehlsen and Albohm 1980; Scurr et al. 2011). Conversely, the frequency of breast motion has been related to lower limb cadence, such that the breasts bounce each time the feet strike the ground, which can be as many as 10,000 times during a 60-minute slow run (McGhee et al. 2013).

Although these previous studies provide valuable biomechanical insight into breast motion during the cyclic activity of running, it is unlikely that this breast motion represents the breast motion experienced when women run over uneven ground or run and rapidly change direction, as required in many sports. Women also perform multidirectional upper and lower limb movements in a variety of sports. Therefore, breast motion recorded during treadmill or overland running in previous studies cannot be
generalised to the breast motion that occurs during the wide variety of sports that women participate in.

Beyond running, researchers have measured the breast motion displayed by women who performed aquatic-based activities such as deep-water running (McGhee et al. 2007), water-based jumping (Mills et al. 2015a) and swimming (Mills et al. 2015b). Several researchers have also analysed the breast motion of women performing a jump (Bridgman et al. 2010; Risius et al. 2015; White et al. 2009a; White et al. 2010), stepping on and off a 240 mm platform (Zhou et al. 2013), performing high-knee lifts (Mason et al. 1999) and during an agility activity where the women ran with maximal effort in the shape of the letter “T” (Risius et al. 2015; White et al. 2010). The researchers conducting these studies have reported that vertical breast displacement was often higher during jumping (9–17.8 cm; Bridgman et al. 2010; Risius et al. 2015; White et al. 2009a) or aerobics (6 cm; Risius et al. 2015) compared to running, although this was not always true for mediolateral or anteroposterior breast motion (Risius et al. 2015; Zhou et al. 2013).

Based on the studies that have investigated breast displacement and acceleration in females during various exercise modalities, breast motion is likely to differ based on the specific sport or type of physical activity a woman is involved in. Considering the high intensity and long duration of training required at an elite level of sport, it is therefore possible that elite female athletes across a range of sports will experience both a high magnitude and frequency of breast motion, and that these variables will depend upon her sport. This high magnitude and frequency of breast motion is potentially detrimental for female athletes because excessive breast motion during physical activity has been associated with breast pain (Gehlsen and Stoner 1987; Haycock et al. 1978; Lawson and Lorentzen 1990; Lorentzen and Lawson 1987; Mason et al. 1999; McGhee et al. 2010b).
1.1.2 Breast pain

Women have been found to experience two distinct types of breast pain during sport and exercise, mastalgia and exercise-induced breast pain (see Chapter 2, Section 2.1). Mastalgia is breast pain that is believed to be hormonal in origin (Ader and Shriver 1997; Brown et al. 2014b; Hadi 2000), occurring in conjunction with a woman’s menstrual cycle and worsening as the result of breast movement during physical activity (Mason et al. 1999; Scurr et al. 2010). Exercise-induced breast pain, on the other hand, is the direct result of breast motion during activity and not associated with the menstrual cycle (Haycock et al. 1978).

In the general population, 44–72% of women have reported experiencing exercise-induced breast pain when they participate in sport and exercise (Gehlsen and Albohm 1980; Haycock et al. 1978; Scurr et al. 2014). This breast pain can often be severe enough to limit a woman’s participation in physical activity (Brown et al. 2014b; Burnett et al. 2015; Lorentzen and Lawson 1987; Mason et al. 1999; McGhee et al. 2013; Page and Steele 1999; Scurr et al. 2016; Shivitz 2001). One simple strategy that has been shown to effectively relieve up to 85% of breast pain symptoms is wearing a properly fitted, high support bra (Hadi 2000), which can reduce breast motion and, in turn, reduce breast pain compared to wearing a bra with a low level of support (McGhee et al. 2010b; Scurr et al. 2010; Scurr et al. 2011). Despite this simple and effective strategy to relieve breast pain, 85–100% of women are reportedly wearing the incorrect bra size (Coltman et al. 2018b; Greenbaum et al. 2003; McGhee and Steele 2006; McGhee and Steele 2010b), which compromises their level of breast support. Therefore, breast pain remains a problem for many women when they participate in sport and exercise.

Considering the high magnitude and frequency of breast motion that elite female athletes are likely to experience, these women might suffer from exercise-induced breast
pain during training and competition. No published studies were found, however, in which the researchers have investigated breast pain experienced by elite female athletes. Furthermore, researchers in only three studies have directly queried female athletes about their experience of breast pain during sport (Brown et al. 2014b; Burbage and Cameron 2017; McGhee et al. 2010a). For example, in a survey of female horse-riders (n = 1265; age range: 18–24 years; bra cup size range: AA–J; bra band size range: 28–44 inches; mode bra size: 34B; see Appendix A for international bra sizing) over 40% of the participants reported experiencing breast pain (Burbage and Cameron 2017). In a survey of women participating in the 2012 London Marathon (n = 1285; bra cup size range: AA–HH; bra band size range: 28–40 inches; mode bra size: 34B) 32% of runners reported experiencing breast pain during activity (Brown et al. 2014b). These two studies, however, were limited to women participating in either horse-riding or marathon running and did not specifically include elite female athletes. Furthermore, neither of these studies distinguished between types of breast pain (mastalgia and exercise-induced breast pain) in their study design (Brown et al. 2014b; Burbage and Cameron 2017). As mastalgia and exercise-induced breast pain are distinct in origin, it is imperative that each type of breast pain is investigated independently.

McGhee et al. (2010) investigated exercise-induced breast pain independently of mastalgia, querying female netball and field hockey players from regional sporting academies (n = 115; mean age: 16 years; bra cup size range: A–DD; Australian bra band size range: 10–14; mean bra size 12B) about the severity of any breast pain they experienced during sport. The participants reported a mean exercise-induced breast pain score of only 2.4 out of a maximum of 10 (Visual Analogue Scale). These participants, however, were all adolescent females (aged 14–18 years). Therefore, the low exercise-induced breast pain scores reported by this cohort only represent breast pain experienced
by female athletes of this adolescent age-range (not adults) and in the two sports of netball and field hockey. No published study was located that specifically investigated the occurrence of mastalgia or exercise-induced breast pain reported by elite female athletes across a diverse range of ages and sports.

In addition to the occurrence of breast pain, it is also important to understand whether breast pain has any negative effects on the sporting performance of an athlete. Although exercise-induced breast pain has been shown to limit participation in physical activity for women in the general female population (Brown et al. 2014b; Burnett et al. 2015; Lorentzen and Lawson 1987; Mason et al. 1999; McGhee et al. 2013; Page and Steele 1999; Scurr et al. 2016; Shivitz 2001), limited research was located in which the potential negative effects of exercise-induced breast pain or mastalgia in female athletes have been investigated. As pain anywhere in the body has the potential to negatively affect muscle activity and, in turn, performance (Bank et al. 2013; Graven-Nielsen et al. 1997; Lund 1993; Valeriani et al. 1999), it is possible that the sporting performance of elite female athletes is negatively affected by the breast pain they experience. Indeed, negative performance effects due to breast pain were reported by 21% of the female horse riders surveyed by Burbage and Cameron (2017). Therefore, it is essential to investigate the occurrence of breast pain experienced by a diverse cohort of elite female athletes who participate in a wide variety of sports, distinguishing clearly between mastalgia and exercise-induced breast pain, as well as the perceived effects of this breast pain on their sporting performance.

1.1.3 Breast Injury

Due to the location of the breasts on the anterior chest wall, the lack of musculoskeletal protection and the extensive superficial capillary networks, female breasts are also vulnerable to injury during sport (Greydanus et al. 1998; Jiang and Ni 2013; Loud and
Micheli 2001). Previous publications have described traumatic injuries, such as contusions and haematomas, to the soft tissue of the breast, with the authors of these publications encouraging female athletes to use breast protection to prevent breast injuries from occurring (Bayne 1968; Gehlsen and Stoner 1987; Haycock et al. 1978; Haycock 1978; Lawson 1991). There is very limited epidemiological data, however, on the occurrence or effects of breast injuries in female athletes.

One of the few published studies that focussed on breast injuries in female athletes was a survey, completed by athletic training staff at American universities (n = 361), of injuries sustained by female collegiate athletes. Sixty percent of the staff who participated in the study reported that breast injuries were the least common injury for this cohort of athletes (Gillette 1975). Possibly because breast injuries were not considered problematic in this study, injuries to the breast or chest have seldom since been specifically investigated, even by researchers who have documented other female-specific sporting injuries (Hägglund et al. 2009; Hilibrand et al. 2015; Langeveld et al. 2012; McCarthy et al. 2013; Peck et al. 2013; Zelisko et al. 1982). There are major limitations, however, in the design of many of these injury studies, particularly in the methods used to record, define and classify injuries. It is likely that these study design limitations might have systematically excluded breast injuries from being reported (see Chapter 4, Section 4.1).

In sports injury research, investigators traditionally record injuries that have been reported by athletes to coaches or athletic trainers (Dönmez et al. 2018; Gillette 1975; Schiff et al. 2010) or that have been diagnosed by team physiotherapists or physicians (Giza et al. 2005; Peck et al. 2013; Wik et al. 2019). These methods of recording sports injuries, however, are unlikely to capture reliable information on breast injuries because female athletes are often reluctant to report these sensitive injuries (Smith et al. 2018), particularly to male athletic staff (Drummond et al. 2007). Furthermore, there is no widely
accepted medical diagnosis for breast injuries sustained during sport and no information about breast injuries was included in the most recent iteration of the Team Physician Consensus Statement on Female Athlete Issues (2018), a publication specifically designed to educate team doctors about injuries that female athletes might sustain. It is therefore likely that traditional sports injury research studies have under-estimated breast injuries by recording only those injuries that were reported to coaches and athletic staff or by relying on the subjective diagnoses of breast injuries by medical professionals (Clarsen and Bahr 2014). As such, directly surveying female athletes is likely to be the most reliable method of recording the true occurrence of breast injuries.

The narrow definition of injury used by many sports injury studies (Clarsen and Bahr 2014) might also have contributed to an under-estimate of breast injury occurrence in the past. That is, researchers typically only record injuries that result in time-loss from training or matches (Dönmez et al. 2018; Engström et al. 1991; Schick et al. 2008) or that require medical attention (Giza et al. 2005; Holland et al. 2018; Peck et al. 2013). It is unknown, however, whether breast injuries are severe enough to remove an athlete from sport or require medical attention, or whether female athletes even seek medical attention for their breast injuries. It is therefore possible that a narrow definition of a sports injury might systematically exclude breast injuries from being recorded, despite their potential to negatively affect athletic performance. An alternative injury definition favoured by many sport-specific injury consensus statements is to record “any physical complaint” (Fuller et al. 2006; Fuller et al. 2007b; Pluim et al. 2009; Timpka et al. 2014). The Consensus Statement on Injury Definitions and Data Collection Procedures for Studies of Injuries in Rugby Union, for example, defines an injury as “any physical complaint, which was caused by a transfer of energy that exceeded the body’s ability to maintain its structural and/or functional integrity, that was sustained by a player during a rugby match.
or rugby training, irrespective of the need for medical attention or time-loss from rugby activities” (Fuller et al. 2007b, page 329). To better understand the scope of breast injuries sustained in sport and whether these injuries affect performance, it is therefore necessary to adopt a definition for breast injuries of “any physical complaint” (Clarsen and Bahr 2014) and record all occurrences of breast injuries during training and competition, irrespective of severity.

Sports injury research also typically requires injuries to be classified into distinct categories based on the region of the body where the injury was sustained and the type of injury (Fuller et al. 2006; Fuller et al. 2007b; Pluim et al. 2009; Timpka et al. 2014). Surveys and reporting forms, however, typically do not include a specific “breast injury” category, thus systematically excluding these injuries from being recorded (Hägglund et al. 2009; Hilibrand et al. 2015; Langeveld et al. 2012; McCarthy et al. 2013; Peck et al. 2013; Zelisko et al. 1982). In fact, no sports injury consensus statement was located that specifically included the breast or chest as a potential injury region, and a “haematoma/contusion/bruise” was frequently listed only as a “muscle and tendon” injury (Fuller et al. 2006; Fuller et al. 2007b; Pluim et al. 2009; Timpka et al. 2014). As the female breast is a unique structure comprised of glandular, adipose and connective tissue without muscle, contusions to the breast do not fall under any current established injury category. It is therefore possible that, if adhering to these traditional injury categories, breast injuries will be under-reported even if female athletes are directly surveyed and a broad “any physical complaint” injury definition is used. Thereby, it is essential that athletes are specifically queried about their experience of breast injuries.

Considering the limitations to traditional injury reporting methods, the narrow injury definitions and the restrictive injury classifications used in previous sport injury research, it is possible that the current perceptions about breast injuries being an
The problem

infrequent issue might be incorrect. This notion is supported by a recent injury survey conducted in America, in which female athletes were specifically asked about their experience of breast injuries (Smith et al. 2018). The researchers found that breast injuries affected nearly 48% of collegiate basketball, soccer, softball and volleyball athletes, but that only 10% of these female athletes reported their breast injuries to medical personnel (Smith et al. 2018). The substantially higher occurrence of breast injuries reported in this study compared to the 1975 survey (Gillette) was attributed to the methodology used, which was to directly survey female athletes about breast injuries rather than merely surveying their athletic trainers, using traditional injury survey techniques. Although this 2018 study provided valuable insight into breast injuries in sport, only collegiate basketball, soccer, softball and volleyball players were included. Given the wide variety of sports that female athletes participate in and the growing popularity of contact sports amongst female athletes (e.g. Australian Football, Rugby; Navaratnam 2017; Rugby Australia 2018), there is a need to further investigate the occurrence, causes and perceived performance effects of breast injuries across a diverse range of sports.

In addition to the breasts being vulnerable to contact injuries, skin around the upper torso and breast is also sensitive to potential chafing or abrasion injuries from repetitive contact with an athlete’s sports bra or uniform (Haycock 1987; Loud and Micheli 2001). “Runner’s nipple” has been extensively reported in both female and male runners, the occurrence of which has been associated with increased running distance (Purim and Leite 2014), higher body mass index (BMI; Helm et al. 2012) and a lack of sports bra use in female athletes (Mailler and Adams 2004). Although numerous studies have investigated runner’s nipple in runners and joggers (Adams 2002; Loud and Micheli 2001; Mailler and Adams 2004; Mailler-Savage and Adams 2006), no research was
located that specifically investigated chafing injuries to the breast or torso experienced by female athletes across a range of sports or how these injuries might affect sporting performance. Therefore, it is also necessary to investigate the occurrence and perceived performance effects of chafing injuries to the skin of the breasts and torso across a greater diversity of sports and to parts of the breast other than just the nipple.

1.1.4 Theoretical Framework

Several models have been developed by researchers to guide all stages of sports injury prevention research, which should also be applied when investigating breast injuries in female athletes. The Team-sport Injury Prevention (TIP) framework (O’Brien et al. 2019, see Figure 1) is a recently-published framework which builds upon several widely-cited injury research models (Finch 2006; Van Mechelen et al. 1992) and emphasises that injury prevention strategies can only be effectively implemented once the injury is fully understood (see Chapter 5, Section 5.1). Specifically, Phase One of the TIP framework recommends that the first step in any injury prevention research is to conduct a comprehensive evaluation of the “current injury situation” and “current injury prevention situation”. Addressing Phase One of the framework is critical to inform further research into breast injury risk and specific mechanisms of injury (Phase Two, TIP framework), as well as the eventual development and implementation of breast injury prevention strategies (Phase Three, TIP framework; O’Brien et al. 2019).

Evaluating the current breast injury situation (Phase One of the TIP framework) requires documentation of the “the type, incidence and severity/burden” of breast injuries, as well as the perceptions of “players, coaches and other staff members” towards breast injury risk. Considering the unique methodological requirements of investigating breast injuries and the lack of data supporting whether breast injuries even occur in elite female athletes, it is necessary to firstly establish the occurrence of breast injuries (i.e. how many
athletes have ever experienced a breast injury) before allocating the substantial resources required to document the specific incidence of breast injuries. Data about the occurrence of breast injuries can then be used to inform future injury surveillance studies to determine the incidence of breast injuries in female athletes (i.e. the frequency of breast injuries relative to the number of hours of sports exposure). Furthermore, an investigation of the causes of breast injuries is vital to understanding and classifying the “types” of breast injuries that female athletes sustain. Therefore, the current breast injury situation can best be established by evaluating the occurrence, causes and perceived performance effects (i.e. severity/burden) of breast injuries reported by female athletes, as well as determining the perception of athletes and associated coaches and medical professionals towards breast injuries.

Figure 1: The Team-sport Injury Prevention (TIP) framework (O’Brien et al. 2019).
According to Phase One of the TIP framework, research into breast injuries should also evaluate the “current injury prevention situation” by investigating the use and perceptions of breast injury prevention strategies (see Chapter 6, Section 6.1). The authors of one previous breast injury study (n = 194) documented that only 2% of female athletes were using any form of breast protection during sport (Smith et al. 2018). Similarly, an investigation into the use of general protective equipment by female Rugby Union players (n = 234) found that none of the participants reported wearing any type of breast or chest padding (Comstock et al. 2005). No published study to-date, however, has documented a comprehensive evaluation of the “current injury situation” or the “current injury prevention situation” pertaining to breast injuries in elite female athletes and therefore it is unknown whether athletes across a wide variety of sports are utilising any form of breast protection or any other strategies to prevent injuries to their breasts.

1.2 Aim

The overall aim of this thesis was to systematically investigate breast pain and breast injuries experienced by female athletes. To achieve this overall thesis aim, two studies were conducted, which are presented in four parts. An exploratory study was first developed to investigate breast pain (Part I) and breast injury (Part II) experienced by elite female athletes. The results of Part II of this thesis revealed that contact breast injuries were reported by significantly more athletes involved in contact sports, such as the contact football codes, and that many of the athletes perceived their breast injuries to negatively affect their sporting performance. Based on these unique findings of Part II of this thesis, a second study was designed, based on Phase One of the TIP framework, to investigate the current breast injury situation and the current breast injury prevention situation in female contact football players (Part III). The breasts and torsos of female contact football players were then characterised in Part IV in order to inform the design
The problem

of future breast protective equipment. The specific purpose of each part of the thesis was to determine the:

(i) occurrence, perceived performance effects and factors relating to breast pain in elite female athletes, clearly distinguishing between mastalgia and exercise-induced breast pain (Part I: Chapters 2 & 3);

(ii) occurrence, causes and perceived performance effects of various types of breast injuries in elite female athletes (Part II: Chapter 4);

(iii) current breast injury and breast injury prevention situation for female contact football players, directly informed by Phase One of TIP framework (Part III: Chapters 5 & 6); and

(iv) breast size, breast position and torso size characteristics of female contact football players in order to inform the design of future breast protective equipment (Part IV: Chapter 7).

The results of each part of the thesis were used to inform future research (Chapter 8.2) and to provide evidence-based recommendations for sports to manage breast pain and breast injury (Chapter 8.3). A schematic of how each part of the thesis contributed to the overall thesis aim is shown in Figure 2.

1.3 Significance of the thesis

Elite female athletes participate in high-intensity training and competition over long durations. As such, these athletes are likely to be susceptible to large amounts of breast motion, which can result in breast pain. Elite athletes may also experience direct blows or friction to the skin of their chest that can result in breast injuries. Despite the potential negative effects associated with breast pain and breast injury and the increased participation of females in contact sports, no published research has investigated breast pain or injury in a cohort of elite female athletes or female contact football players. The
present thesis contains the first comprehensive research to specifically investigate the occurrence, causes and perceived performance effects of breast pain and breast injury in elite female athletes, the current breast injury and breast injury prevention situation for female contact football players and the breast and torso characteristics of female contact football players. The ultimate goal of this thesis was to inform future research into breast pain and breast injury and provide evidence-based recommendations for sports to manage breast pain and breast injury.
The problem

Thesis aim: To systematically investigate breast pain and breast injury in female athletes

Figure 2: Schematic representation of the thesis structure and how each part contributes to the overall thesis aim.
Part I

Breast pain in elite female athletes
Chapter 2

Breast pain affects the performance of elite female athletes


Abstract

Although breast pain is problematic for many active women, no published research has investigated breast pain experienced by elite female athletes. This study aimed to examine the extent to which mastalgia and exercise-induced breast pain affected the sporting performance of elite female athletes during training and competition. A custom-designed online survey with questions related to sport participation, as well as the frequency, severity and perceived performance effects of mastalgia and exercise-induced breast pain, was distributed to sporting organisations, coaches, medical staff and teams/clubs throughout Australia. Five hundred forty female athletes competing nationally or internationally across 49 different sports participated in the survey. Thirty-three percent of athletes reported that their mastalgia worsened during activity and 44% reported experiencing exercise-induced breast pain during training or competition. Both types of breast pain were also reported to negatively affect sporting performance (20% and 32%, respectively). Mastalgia associated with the menstrual cycle and exercise-induced breast pain should be acknowledged as potential impediments to the sporting performance of elite female athletes. Awareness around the negative effects of breast pain and the development and implementation of breast pain management strategies is essential for this population.
Breast pain

2.1 Introduction

Female breasts move relative to the trunk when women participate in physical activity. It is the magnitude and frequency of this movement that determines the total breast movement a woman will experience when exercising. The magnitude of breast movement increases with greater breast mass (Haake and Scurr 2010; Lorentzen and Lawson 1987; Wood et al. 2012) and greater trunk, arm and lower extremity movement (Chen et al. 2016; Gehlsen and Albohm 1980; Scurr et al. 2011). In contrast, the frequency of breast movement is determined by the rate of breast bounce and the duration of an activity. Increases in either the magnitude or frequency of breast bounce will contribute to higher overall breast movement, which has been associated with breast pain in many women (Chen et al. 2016; Gehlsen and Albohm 1980; Lorentzen and Lawson 1987; Mason et al. 1999; McGhee et al. 2006; McGhee et al. 2013; Risius et al. 2015; Scurr et al. 2010; Scurr et al. 2011; White et al. 2009b). This breast pain is commonly referred to in the literature as exercise-induced breast discomfort or exercise-induced breast pain and has been reported to affect 44–72% of the general female population (Gehlsen and Albohm 1980; Haycock et al. 1978; Scurr et al. 2014). Many women also experience cyclic breast pain, referred to as mastalgia, which can be further exacerbated by breast motion during physical activity (Mason et al. 1999; Scurr et al. 2010). Mastalgia has been reported to affect 51–79% of the general female population (Ader and Shriver 1997; Scurr et al. 2014).

Only limited research has been conducted to investigate the occurrence of breast pain reported by female athletes. A survey of female horse-riders (n = 1265; bra cup size AA–J) revealed that 40% of the respondents experienced some type of breast pain, with 60% of these women reporting breast pain around the time of their period and 29% reporting breast pain during horse-riding (Burbage and Cameron 2017). An investigation
of the breast pain experienced by women participating in the 2012 London Marathon (n = 1285; bra cup size AA–HH) similarly found that 32% of the respondents experienced breast pain, with 52% reporting that their breast pain was related to their menstrual cycle and 30% reporting that it was sometimes related to their menstrual cycle (Brown et al. 2014b). Although these study findings support the notion that breast movement can aggravate breast pain in an athletic population, participants in both studies were asked to report collectively on all breast pain they experienced (i.e. exercise-induced breast pain and pain related to the menstrual cycle). Therefore, the authors of the reports (Brown et al. 2014b; Burbage and Cameron 2017) were limited in the conclusions they could draw as to the relationship between breast movement and specific types of breast pain. Furthermore, neither study classified the athletic level of the participants (i.e. whether the participants were recreational or elite athletes) and both studies focused only on a single athletic cohort (equestrian riders or distance runners). As data obtained from recreational athletes might not represent the breast motion and pain experienced by elite athletes, and because breast movement and therefore breast pain differs between different exercise modalities and sports, these findings cannot be extrapolated to an elite athletic population (Risius et al. 2015).

At an elite level of sport, athletes typically perform high intensity movements over an extended duration of training and competition hours. It is therefore likely that elite female athletes experience a high level of total breast movement and, in turn, a high level of breast pain. As pain anywhere in the body has the potential to negatively affect sporting performance (Bank et al. 2013; Graven-Nielsen et al. 1997), it is also possible that elite female athletes suffer performance effects as a result of exercise-induced breast pain or mastalgia (Brown et al. 2014b; Burbage and Cameron 2017). In fact, excessive breast motion has been previously linked to alterations in gait kinematics, ground reaction forces
Breast pain

and upper limb muscle activation during running (Milligan et al. 2014; Risius et al. 2017; White et al. 2009b), further supporting the notion that breast pain might negatively affect optimal technique and therefore sporting performance. No research to date, however, has identified the extent to which elite athletes experience different types of breast pain or whether this breast pain affects their performance.

This study aimed to investigate the occurrence and severity of mastalgia and exercise-induced breast pain in elite female athletes across a diverse range of sports and the effect of both types of breast pain on sporting performance. Based on the current literature, it was hypothesised that:

H1: elite female athletes would experience a similar occurrence of mastalgia to the general female population, and that this pain would be exacerbated by physical activity;
H2: elite female athletes would experience a higher occurrence of exercise-induced breast pain compared to recreationally active females;
H3: elite female athletes would perceive mastalgia and exercise-induced breast pain to have a negative effect on their sporting performance; and
H4: the occurrence and severity of exercise-induced breast pain reported by elite female athletes would vary across different sport-related activities.

2.2 Design and methods

2.2.1 Survey development and design

Following an extensive review of the literature and numerous discussions with relevant stakeholders (e.g. sport scientists, coaches, clinicians and athletes), an anonymous 42-question online survey was designed to gather data on any breast issues experienced by elite female athletes. Factors associated with these issues, such as their breast characteristics and bra wearing habits, were also questioned. Face validity of the survey
was verified through a series of interviews with female athletes \((n = 16)\) competing nationally or internationally in a range of sports \((n = 6)\), where the think-aloud technique (Whitney and Budd 1996) was also used to confirm that the athletes understood the questions and that appropriate sport-specific language was used. Based on this feedback, the survey was modified and the final version, containing 36 close-ended questions and 6 open-ended questions relating to sport participation, breast characteristics and breast issues, was published on Qualtrics \((v0217;\text{Provo, UT})\). An identical hard copy of the survey was also distributed at training camps and competitions around Australia (a full copy of the survey is provided in Appendix B).

### 2.2.2 Survey implementation

Inclusion criteria were female athletes, 18 years of age or older, who were training/competing in any sport at a national or international level (Swann et al. 2015). For individuals involved in sports that do not have organised national or international competitions (e.g. trail running), eligibility was determined using standards relevant to the sport (e.g. race qualification). Athletes satisfying the above inclusion criteria were indirectly recruited to participate by contacting (via email, telephone or face-to-face meetings) coaches, administrators and medical staff associated with female sports, who could then elect to share the study details with their athletes. Information about the study and a direct link to the online survey was also shared on several national and state sporting organisation social media sites; in training facilities at the Australian Institute of Sport (AIS); through conferences and presentations; and in medical practitioner offices. Hard copies of the survey were also available upon request (de Bernardo and Curtis 2013) and were distributed at training camps and sporting competitions in the Australian states of New South Wales, Queensland, Australian Capital Territory, Western Australia and Victoria. The survey was activated in June 2017 and was closed in March 2018,
Breast pain

further promotion of the study failed to illicit new responses. Participants were deemed to have given tacit consent to participate if they completed the survey after reading the participant information sheet on the opening page of website or the front page of the hard copy. The University of Wollongong Human Research Ethics Committee (HREC 2017/009) and the AIS Ethics Committee (20170610) approved the survey design and all implementation procedures.

2.2.3 Analytical variables

Occurrence of mastalgia: Participants were asked about when they experienced mastalgia (breast pain associated with their menstrual cycle), with potential responses “always”, “around the time of my period” and “never”. If a participant indicated they did experience mastalgia (either “always” or “around the time of my period”), they were asked whether their mastalgia was typically worsened by breast movement during training or competition, to which they could respond “yes” or “no”.

Perceived performance effects of mastalgia: Participants were then asked whether they perceived that their mastalgia negatively affected their sporting performance (“yes” or “no”).

Exercise-induced breast pain: Participants were asked about how frequently they experienced exercise-induced breast pain (caused by breast motion) during training or competition on a five-point Likert scale ranging from “always” (score = 1) to “never” (score = 5). Responses “always” to “a little of the time” (scores 1 to 4) were then classified as “yes” and the response “never” (score = 5) was classified as “no” to present an overall occurrence of exercise-induced breast pain.

Perceived performance effects of exercise-induced breast pain: Participants who reported exercise-induced breast pain were then asked to respond either “agree” or
“disagree” to whether breast pain negatively affects their ability to train and whether breast pain negatively affects their performance in competition.

**Severity of exercise-induced breast pain during activities:** Participants who reported exercise-induced breast pain were asked to rank the severity of their exercise-induced breast pain on a five-point Likert scale from “very severe” (score = 1) to “no breast pain” (score = 5) during a series of nine different sports-related activities, if these activities were relevant to their sport (see Table 2). If an activity was not associated with an athlete’s sport (e.g. throwing for a sprinter), participants were asked to indicate “N/A” for that response. Responses of “very severe” (score = 1) to “mildly severe” (score = 4) were considered as a confirmation (“yes”) of experiencing exercise-induced breast pain during that particular activity. The response “no breast pain” was deemed a negative response (“no”) to experiencing exercise-induced breast pain during that particular activity.

### 2.2.4 Statistical analysis

**Descriptive statistics:** Responses to the questions described above were coded and then counted to determine the relative frequency of each possible response. For mastalgia, exercise-induced breast pain and the perceived performance effects of each pain type, a frequency count (of “yes”) was used to determine overall occurrence of each variable. For the nine sport-related activities ranked on a 5-point Likert scale from “very severe” to “not severe”, a frequency count for each point on the scale was presented. The overall occurrence (sum of all scores excluding “no breast pain”) and mean severity (average of all participant scores for that particular activity) were also presented. A mean value closer to 1 indicated that the participant experienced more severe breast pain during that particular activity and a mean value closer to 5 indicated that the participant experienced less severe breast pain during that particular activity. As the number of total responses for each question differed from the overall number of survey participants because some
Breast pain

questions were only displayed if specific conditions were met, pairwise deletion of missing data was used to retain the largest possible sample size for each individual analysis. If a participant intentionally did not complete a question, the blank response was treated as “N/A” and removed from the data for that question only.

**Linear mixed model:** The exercise-induced breast pain severity data, ranked from “very severe” (score = 1) to “no breast pain” (score = 5) during the nine different sport-related activities, were restructured into long form (each activity for each participant occupying a separate row) in the Statistical Package for the Social Sciences (Version 23; SPSS Inc., Chicago, USA). A Linear Mixed Model was then used to determine whether activity type had any significant \( p < 0.05 \) effect on the reported severity of exercise-induced breast pain. This statistical test was chosen because it allowed comparisons between repeated group means to be analysed when data were missing (participants were only asked to rate activities relevant to their sport) and for its robustness to non-normal distributions when working with large samples. A Bonferroni *post-hoc* test was also performed to generate pairwise comparisons between each activity on the basis of the mean difference in reported severity on the five-point Likert-scale.

2.3  Results

2.3.1  Participant characteristics

A total of 540 female athletes, whose characteristics are listed in Table 1, completed the survey. The participants competed in 49 different sports and included representatives from national and international competitions, including International Masters Games, Commonwealth Games and Olympic Games. National-level athletes comprised 59% of participants and international-level athletes comprised 32%. The remaining 9% of participants indicated an “other” competitive level and were included based on additional information provided about their sport, competition history and training hours.
### Table 1: Characteristics of the 540 elite female athletes who completed the survey compared to physical characteristics of a sample of Australian women from the general population.

<table>
<thead>
<tr>
<th></th>
<th>Participants</th>
<th>Australian Women&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>Age (years)</td>
<td>18</td>
<td>71</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>140</td>
<td>201</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>41</td>
<td>120</td>
</tr>
<tr>
<td>Body Mass Index (kg/m²)</td>
<td>15.4</td>
<td>37.9</td>
</tr>
<tr>
<td>Bra size&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8A</td>
<td>20G</td>
</tr>
</tbody>
</table>

<sup>a</sup>Australian Women data sourced from a previous publication (Coltman et al. 2017b).

<sup>b</sup>Average bra size in both samples was reported as the mean bra band size and the mode bra cup size based on Australian bra sizing (see Appendix A for international bra sizing).

#### 2.3.2 Mastalgia

The overall occurrence of mastalgia was 63% (n = 327), of which 33% of participants (n = 100) reported that their mastalgia was exacerbated by physical activity. One-fifth of these participants also perceived that their mastalgia was severe enough to negatively affect their sporting performance.

#### 2.3.3 Exercise-induced breast pain

The overall occurrence of exercise-induced breast pain was 44% (n = 228), with a further 37% (n = 84) of participants reporting that their exercise-induced breast pain interfered with their ability to train. Thirty-two percent (n = 73) of the participants reporting exercise-induced breast pain perceived that the pain was severe enough to negatively affect their sporting performance. The severity of exercise-induced breast pain experienced during nine different sport-related activities is presented in Table 2. The activities that were associated with the most severe exercise-induced breast pain (scores closer to 1) were running, jumping and landing. Activity type was found to have a significant effect on the reported severity of breast pain (<i>p</i> < 0.001). The activities that
were reported to cause significantly more exercise-induced breast pain relative to other activities are marked with an asterisk in Table 3.
Table 2: The total number of responses (n) and the frequency count of participants reporting exercise-induced breast pain at each of 5 points on the scale (from very severe, score = 1 to no breast pain, score = 5). All responses were averaged to report an overall mean severity for each activity (95% confidence interval), and scores 1–4 ("yes" breast pain) were counted and divided by the total number of responses to represent the percentage of participants who experienced exercise-induced breast pain during each activity (occurrence).

<table>
<thead>
<tr>
<th>Activity</th>
<th>n</th>
<th>Very severe (n)</th>
<th>Severe (n)</th>
<th>Moderate (n)</th>
<th>Mild (n)</th>
<th>No breast pain (n)</th>
<th>Mean severity (1= Very severe; 5= No pain) (95% CI)</th>
<th>Occurrence (scores 1–4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jumping</td>
<td>200</td>
<td>6</td>
<td>15</td>
<td>56</td>
<td>87</td>
<td>36</td>
<td>3.66 (3.53–3.79)</td>
<td>82%</td>
</tr>
<tr>
<td>Running</td>
<td>210</td>
<td>9</td>
<td>10</td>
<td>52</td>
<td>91</td>
<td>48</td>
<td>3.76 (3.62–3.89)</td>
<td>77%</td>
</tr>
<tr>
<td>Landing</td>
<td>177</td>
<td>2</td>
<td>13</td>
<td>37</td>
<td>65</td>
<td>60</td>
<td>3.95 (3.80–4.09)</td>
<td>66%</td>
</tr>
<tr>
<td>Jogging</td>
<td>204</td>
<td>2</td>
<td>5</td>
<td>31</td>
<td>82</td>
<td>84</td>
<td>4.18 (4.06–4.30)</td>
<td>59%</td>
</tr>
<tr>
<td>Throwing</td>
<td>175</td>
<td>0</td>
<td>3</td>
<td>11</td>
<td>21</td>
<td>140</td>
<td>4.70 (4.60–4.80)</td>
<td>20%</td>
</tr>
<tr>
<td>Swinging</td>
<td>162</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>22</td>
<td>131</td>
<td>4.74 (4.64–4.83)</td>
<td>19%</td>
</tr>
<tr>
<td>Catching</td>
<td>174</td>
<td>0</td>
<td>3</td>
<td>6</td>
<td>19</td>
<td>146</td>
<td>4.77 (4.68–4.86)</td>
<td>16%</td>
</tr>
<tr>
<td>Kicking</td>
<td>157</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>14</td>
<td>137</td>
<td>4.82 (4.73–4.90)</td>
<td>13%</td>
</tr>
<tr>
<td>Walking</td>
<td>193</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>17</td>
<td>170</td>
<td>4.85 (4.78–4.91)</td>
<td>12%</td>
</tr>
</tbody>
</table>
Table 3: Mean difference of the reported severity of exercise-induced breast pain (rated on a 5-point Likert scale) between nine sport-related activities. An activity (row) was considered to induce more exercise-induced breast pain than another activity (column) if the mean difference was a negative value because this number represents a decrease in the pain score towards 1, or "very severe".

<table>
<thead>
<tr>
<th>Activity</th>
<th>Walking</th>
<th>Jogging</th>
<th>Running</th>
<th>Jumping</th>
<th>Landing</th>
<th>Throwing</th>
<th>Catching</th>
<th>Swinging</th>
<th>Kicking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>--</td>
<td>.663*</td>
<td>1.087*</td>
<td>1.185*</td>
<td>.895*</td>
<td>.142</td>
<td>.074</td>
<td>.110</td>
<td>.029</td>
</tr>
<tr>
<td>Jogging</td>
<td>-1.087*</td>
<td>--</td>
<td>.424*</td>
<td>.521*</td>
<td>.232</td>
<td>-.521*</td>
<td>-.589*</td>
<td>-.553*</td>
<td>-.634*</td>
</tr>
<tr>
<td>Running</td>
<td>-.663*</td>
<td>-.424*</td>
<td>--</td>
<td>.097</td>
<td>-.192</td>
<td>-.946*</td>
<td>-1.013*</td>
<td>-.977*</td>
<td>-1.058*</td>
</tr>
<tr>
<td>Jumping</td>
<td>-1.185*</td>
<td>-.521*</td>
<td>-.097</td>
<td>--</td>
<td>-.289</td>
<td>-1.043*</td>
<td>-1.110*</td>
<td>-1.075*</td>
<td>-1.155*</td>
</tr>
<tr>
<td>Landing</td>
<td>-.895*</td>
<td>-.232</td>
<td>.192</td>
<td>.289</td>
<td>--</td>
<td>-.754*</td>
<td>-.821*</td>
<td>-.785*</td>
<td>-.866*</td>
</tr>
<tr>
<td>Throwing</td>
<td>-.142</td>
<td>.521*</td>
<td>.946*</td>
<td>1.043*</td>
<td>.754*</td>
<td>--</td>
<td>-.067</td>
<td>-.032</td>
<td>-.112</td>
</tr>
<tr>
<td>Catching</td>
<td>-.074</td>
<td>.589*</td>
<td>1.013*</td>
<td>1.110*</td>
<td>.821*</td>
<td>.067</td>
<td>--</td>
<td>.036</td>
<td>-.045</td>
</tr>
<tr>
<td>Swinging</td>
<td>-.110</td>
<td>.553*</td>
<td>.977*</td>
<td>1.075*</td>
<td>.785*</td>
<td>.032</td>
<td>-.036</td>
<td>--</td>
<td>-.081</td>
</tr>
<tr>
<td>Kicking</td>
<td>-.029</td>
<td>.634*</td>
<td>1.058*</td>
<td>1.155*</td>
<td>.866*</td>
<td>.112</td>
<td>.045</td>
<td>.081</td>
<td>--</td>
</tr>
</tbody>
</table>

* indicates significant at \( p < 0.05 \)
2.4 Discussion

This is the first study to investigate the occurrence and severity of specific types of breast pain experienced by elite female athletes and how this breast pain was perceived to affect their sporting performance. Mastalgia and exercise-induced breast pain were commonly experienced by the participants, and both types of breast pain were reported to negatively affect sporting performance. Furthermore, the severity of exercise-induced breast pain was significantly higher during activities such as running, jumping and landing compared to walking. The implications of these findings are discussed below.

2.4.1 Mastalgia

Limited research has previously investigated the occurrence of mastalgia experienced by active females and no published study was found that reported on this cyclic breast pain in elite female athletes. However, sixty-three percent of survey respondents in this study, who were elite female athletes, reported suffering from mastalgia. This finding supports the first hypothesis (H1) that the level of mastalgia in elite athletes would be consistent with that of non-elite active women (Brown et al. 2014b; Burbage and Cameron 2017) and the general female population (51–79%) (Ader and Shriver 1997; Scurr et al. 2014). Furthermore, it was found that 20% of athletes who reported mastalgia also reported that their mastalgia negatively affected their sporting performance, confirming the third hypothesis (H3). It is therefore critical that strategies are developed to minimise the potential for mastalgia to impair sporting performance. One simple strategy that has been shown to effectively relieve up to 85% of breast pain symptoms is wearing a properly fitted, supportive bra (Brown et al. 2014b; Hadi 2000). Therefore, elite female athletes need to be educated on the importance of adequate breast support and how to select and correctly fit a sports bra that caters for the movements specific to their sport. Education has been shown to improve bra fit and breast support (McGhee et al. 2010a) which, in
Breast pain

turn, could reduce the occurrence and negative performance effects of mastalgia in this population. Future research is also recommended to investigate whether there are specific phases of the menstrual cycle during which mastalgia is more prevalent in elite female athletes so that strategies can be tailored to when they are needed most.

2.4.2 Exercise-induced breast pain

Exercise-induced breast pain was found to affect nearly half of all the elite female athletes who responded to the survey. Contrary to the second hypothesis (H2), however, this cohort of athletes did not experience a higher occurrence of exercise-induced breast pain compared to the general female population or non-elite female athletes. Instead, the participants reported a level of exercise-induced breast pain that was consistent with the lower end of values that have been reported in previous literature (44–72%; Gehlsen and Albohm 1980; Haycock et al. 1978; Scurr et al. 2014). Although elite female athletes typically experience a high frequency of breast movement due to long training hours, they might experience a lower magnitude of breast movement due to having, on average, a relatively smaller breast size and younger age compared to the general female population (Mason et al. 1999; McGhee et al. 2010a). This would explain why the percentage of participants in this study who reported exercise-induced breast pain was similar to that of their non-athletic counterparts. Irrespective of this comparison, it is imperative to understand the effects of exercise-induced breast pain on sporting performance because nearly half of the participants in this study reported suffering from this pain during training and competition. It is recommended that future research investigate the severity of exercise-induced breast pain experienced by elite female athletes, its association with training volume and how strategies currently used by elite female athletes to reduce breast pain affect their sporting performance. The incidence and severity of exercise-induced
breast pain in elite female athletes should also be compared to a control group of non-elite athletes.

Thirty-two percent of the participants who reported experiencing exercise-induced breast pain also reported that this pain had a negative effect on their performance, partially confirming the second hypothesis (H2). These findings further emphasise the need for improved breast pain management strategies, such as education for female athletes about the importance of wearing a properly fitted, high support sports bra, which has been shown to reduce excessive breast motion and, in turn, reduce exercise-induced breast pain when compared to a bra with a low level of support (McGhee et al. 2010b; Scurr et al. 2010; Scurr et al. 2011). It is possible, however, that commercially available sports bras do not meet the unique needs of elite female athletes across the range of sports they participate in. Considering the varied sport-specific movements that athletes perform and their long training and competition hours, the breast support needs of these women might differ from those of the general female population. Therefore, current sports bras may not sufficiently reduce excessive breast motion and resultant breast pain during some sports, explaining the high percentage of elite female athletes who reported exercise-induced breast pain.

The considerable variance in severity of exercise-induced breast pain reported by participants across the nine different sport-related activities (H3) provides further support for the notion that sports bras might not be sufficiently supportive for some elite athletes. Both the highest occurrence and greatest mean severity of exercise-induced breast pain (where a score of 1 represented “very severe” and a score of 5 represented “no breast pain”) was reported during jumping (82%; 3.66), followed by running (77%; 3.76) and landing from a jump/dismount (66%; 3.95). These results are consistent with previous research, which has shown that running and jumping movements involve greater overall...
Breast pain

breast movement compared to walking (Bridgman et al. 2010; Mason et al. 1999; McGhee et al. 2007; Risius et al. 2015; White et al. 2009b). Although all pain scores only fell within the “moderately severe” to “mildly severe” categories, this might be explained by participants ranking the severity of their breast pain relative to other types of sport pain and injuries (e.g. sprains, fractures), which may have under-estimated the overall severity. Irrespective of the scores, one-third of participants perceived that exercise-induced breast pain negatively affected their sporting performance, justifying the need for breast pain management strategies specific to elite female athletes. The difference in pain scores between the nine sport-related activities also suggests that future breast support recommendations need to be specific to the movements an athlete is likely to perform.

As this current study relied entirely upon self-reported survey data, it is necessary to acknowledge the limitations associated with subjective variables such as pain scores. In order to reduce potential errors in future studies, it is recommended to record objective indicators of the severity of breast pain (e.g. number of games and duration of game experiencing pain), as well as using negative performance detriments (Y/N) as a benchmark for severity. Such an objective scale could replace the Likert-scale, which requires participants to individually classify what is “severe” to them, and which is unlikely to be consistent between athletes. Although every effort was made to recruit a representative sample of elite female athletes, it is also possible that athletes who had experienced breast pain were more likely to respond to the survey.

2.5 Conclusion

Mastalgia and exercise-induced breast pain were reported by elite female athletes, and both types of breast pain were perceived to negatively affect the sporting performance of these athletes. Exercise-induced breast pain was also significantly related to the type of activity, with different severities of pain reported during fundamental sport activities such
as jumping, throwing and kicking. Coaches, allied health and medical professionals associated with elite female sport, as well as the athletes themselves, should be made aware of the potential for breast pain to negatively affect sporting performance. More importantly, evidence-based strategies to prevent and manage breast pain for elite female athletes need to be developed, implemented and evaluated.
Chapter 3

Can physical characteristics and sports bra use predict exercise-induced breast pain in elite female athletes?


Abstract

Elite female athletes experience exercise-induced breast pain during training and competition that is often severe enough to negatively affect their sporting performance. This study aimed to evaluate whether a simple 4-factor model using self-reported data could be used to predict exercise-induced breast pain in elite female athletes. A custom-designed online survey that included questions about physical characteristics and frequency of sports bra use was distributed to sporting organisations, clubs and teams across Australia. A binomial logistic regression analysis was used to evaluate the strength of a predictive model for exercise-induced breast pain that included two continuous independent variables (age and BMI) and two binary independent variables (breast size and sports bra use). Four hundred ninety female athletes competing nationally or internationally across a range of sports participated in the survey. The model was found to be statistically significant, but weak, in its ability to predict exercise-induced breast pain in elite female athletes (correctly identified 66% of athletes). Future research is encouraged to investigate whether incorporating additional variables such body fat percentage, bra fit and other relevant factors can add strength to the model.
3.1 Introduction

Breast motion during physical activity has been linked to breast pain in a high percentage of women. Termed exercise-induced breast pain or discomfort, this breast pain has been found to affect 44–72% of active females (Gehlsen and Albohm 1980; Haycock et al. 1978; Scurr et al. 2014) and approximately 44% of elite female athletes (see Chapter 2). In the general population, exercise-induced breast pain is often severe enough to reduce a woman’s participation in physical activity (Bowles et al. 2008; Lorentzen and Lawson 1987; Mason et al. 1999), whereas in elite female athletes, breast pain has been reported to negatively affect sporting performance (see Chapter 2; Burbage and Cameron 2017). It is therefore important to understand how factors that contribute to exercise-induced breast pain can be used to identify female athletes who are particularly susceptible to this pain. This will enable coaches and clinical professionals associated with athletes to reduce negative performance effects by encouraging players to utilise appropriate prevention strategies.

The female breast has no muscular or skeletal support; anatomical support is provided only by a lattice-like network of suspensory ligaments, called Cooper’s ligaments, and the skin overlying the breast (Gefen and Dilmoney 2007; Haycock 1987; Mason et al. Fallon 1999). Although no research has investigated age-related changes to the Cooper’s ligaments, the viscoelastic properties of breast skin change with age, whereby the elasticity and extensibility of skin significantly decrease around 25 years of age (Coltman et al. 2017c) and skin thickness dramatically decreases after the onset of menopause (Coltman et al. 2017c; Gefen and Dilmoney 2007). The anatomical supports of the breasts are therefore likely to decrease as women age, resulting in greater breast movement and associated exercise-induced breast pain, which could in turn negatively affect the sporting performance of older elite female athletes. Similarly, limited research
Breast pain model

has associated parity with increases in breast volume around the time of menopause (Den Tonkelaar et al. 2004; Efting Dijkstra 1995), which then has the potential to further dispose athletes to breast pain during sport. Age might therefore be a predictor of exercise-induced breast pain in athletes, although this notion has never been investigated.

Breast size is the most researched factor that contributes to breast motion and exercise-induced breast pain, with numerous studies reporting a significant association between larger breasts and higher levels of exercise-induced breast pain in the general female population (Bridgman et al. 2010; Brown et al. 2014a; Lorentzen and Lawson 1987). Although similar associations have been observed in active women and sub-elite female athletes (Brown et al. 2014b; Burbage and Cameron 2017), the relationship between breast size and exercise-induced breast pain has yet to be investigated in an elite athletic population, possibly because elite athletes are often presumed to have small breasts (Mason et al. 1999). However, respondents to a survey of 540 elite female athletes from 49 different sports (see Chapter 2) reported bra sizes ranging from 8–20G (Australian bra sizing system; see Appendix A for international bra sizing). Nearly one-quarter of these respondents had breasts that were classified as medium, large or hypertrophic sizes (based on the bra size to breast volume conversion presented in Table 4), suggesting that although elite female athletes have a smaller breast size on average compared to the general female population (see Chapter 2, Section 2.4.2), these athletes still have a wide range of breast sizes. Therefore, breast size might also be able to predict exercise-induced breast pain in elite female athletes.

Breast size is strongly associated with body mass index (BMI), whereby up to 50% of the variation in breast volume can be explained by a woman’s BMI (Brown et al. 2012; Coltman et al. 2017b). Furthermore, overweight and obese women have 2-3 times the breast volume of women with a normal BMI (Coltman et al. 2017b). As female
Breast pain model

athletes are known to have unique body composition and generally lower BMIs than the general population (Byrne and McLean 2002; Sundgot-Borgen and Larsen 1993; Sundgot-Borgen and Torstveit 2004; Torstveit and Sundgot-Borgen 2005), it is not known whether BMI can predict exercise-induced breast pain in female athletes.

In addition to a woman’s physical characteristics such as breast size, the use of external breast support has also been associated with exercise-induced breast pain. Numerous studies have shown that wearing a correctly fitted, high support sports bra will significantly decrease breast movement and, in turn, exercise-induced breast pain compared to wearing a low support sports bra (Lorentzen and Lawson 1987; McGhee et al. 2010b; McGhee et al. 2013; Scurr et al. 2010). Therefore, frequency of sports bra use might also be a relevant predictor of exercise-induced breast pain, although the current use of sports bras by elite female athletes is unknown.

This study aimed to investigate whether a model using age, breast size, BMI and sports bra use could predict the likelihood that an elite female athlete would experience self-reported exercise-induced breast pain. Such a model would assist coaches and clinical professionals to recommend appropriate strategies to reduce the negative performance effects associated with exercise-induced breast pain, thus promoting better management of this medical condition. Based on the current literature, it was hypothesised that:

H1: a model using age, breast size, BMI and sports bra use would be able to correctly predict which athletes reported exercise-induced breast pain and those who did not;

H2: increased age, breast size and BMI would each increase the likelihood of an athlete reporting exercise-induced breast pain; and
H3: increased frequency of sports bra use would decrease the likelihood of an athlete reporting exercise-induced breast pain.

3.2 Design and methods

3.2.1 Survey design and implementation

An anonymous 42-question survey was designed to gather data on sport participation, sports bra use and breast pain experienced by female athletes, aged 18 years or older, currently competing nationally or internationally (i.e. representing their state or country) in any sport. The survey design, recruitment and study approval procedures were the same as those listed in Chapter 2, Sections 2.2.1 and 2.2.2. In brief, athletes satisfying the above inclusion criteria were indirectly recruited to participate by contacting coaches, administrators and medical staff associated with female sports, who could then elect to share the study details with their athletes. Participants were also consistent with those reported in Chapter 2, Section 2.3.1, although data from participants who did not answer all questions relevant to the current study were excluded from the analysis (see Section 3.3.1 below).

3.2.2 Analytical variables

Exercise-induced breast pain: Participants were asked how frequently they experienced exercise-induced breast pain during training or competition on a five-point Likert scale ranging from “always” (score = 1) to “never” (score = 5). Due to low frequency counts in several of the groups, responses “always” (score = 1) to “a little of the time” (score = 4) were collapsed into the category “yes”. This created a binary variable (“yes” or “no”) for the regression analysis.

Age: Participants recorded their date of birth, which was then used to calculate age (as a continuous numerical variable) from the date of survey completion.

Breast size: Participants were asked “What is your bra size? If you do not know your
exact bra size, please estimate to the best of your ability. Write the band size & cup size (e.g. 8B, 32DD).” Published data on bra size and breast volume (Coltman et al. 2014; Coltman et al. 2017b; McGhee and Steele 2011) were used to determine an approximate range of breast volumes that corresponded to each bra size (see Appendix A for international bra sizing). Bra sizes could then be sorted into one of four previously-defined breast size categories: Small (<350 ml), medium (350–700 ml), large (701–1200 ml) or hypertrophic (>1200 ml) (Coltman et al. 2017b). As shown in Table 4, a reference table was then created to assign each participant into a breast size category based on her self-reported bra size. Due to low frequency counts in several of the groups, “medium breasts”, large breasts” and “hypertrophic breasts” (scores 2–4) were collapsed into the category “medium-to-hypertrophic breasts”. This created a binary variable (“small breasts” or “medium-to-hypertrophic breasts”) for the regression analysis.

**Table 4:** Australian (and US) bra sizes grouped into four breast size categories (Coltman et al. 2017b) based on approximate breast volume: 1 = small breasts (<350 ml); 2 = medium breasts (350–700 ml); 3 = large breasts (701–1200 ml); and 4 = hypertrophic breasts (>1200 ml).

<table>
<thead>
<tr>
<th>Band size</th>
<th>Cup size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A cup</td>
</tr>
<tr>
<td>8 (30)</td>
<td>1</td>
</tr>
<tr>
<td>10 (32)</td>
<td>1</td>
</tr>
<tr>
<td>12 (34)</td>
<td>1</td>
</tr>
<tr>
<td>14 (36)</td>
<td>1</td>
</tr>
<tr>
<td>16 (38)</td>
<td>1</td>
</tr>
<tr>
<td>18 (40)</td>
<td>2</td>
</tr>
<tr>
<td>20 (42)</td>
<td>2</td>
</tr>
</tbody>
</table>

**Body Mass Index:** Participants self-reported their height in centimetres and body mass in kilograms. Each participant’s BMI (continuous numerical variable) was then calculated by dividing her mass by her height, squared (kg/m²).
**Frequency of sports bra use:** Participants were asked how frequently they wore any form of sports bra (either a compression crop top, an encapsulation sports bra or a “hybrid” encapsulation bra with a compressive outer layer) during training and competition on a five-point Likert scale ranging from “always” (score = 1) to “never” (score = 5). Photos and descriptions of each bra type were included in the survey. Due to low frequency counts in several of the groups, responses “most of the time”, “some of the time”, “a little of the time” and “never” (scores 2–5) were collapsed into the category “less than always”. This created a binary variable (“always” or “less than always”) for the regression analysis.

3.2.3 **Statistical analysis**

**Descriptive statistics:** Minimum, maximum, mean and standard deviation values for the participant characteristics (age, height, body mass and BMI) were calculated for all participants (n = 490), as well as grouped by participants who reported exercise-induced breast pain (n = 218) and those who did not (n = 272).

**Binomial logistic regression:** An ordinal logistic regression model, maintaining the five levels of the ordinal dependent variable (frequency of breast pain) and all levels of the categorical independent variables (breast size and frequency of sports bra use), would typically be used in this type of study. However, in the present study, 79.7% of cells returned zero frequency based on the number of covariate patterns, and therefore a binomial logistic regression was chosen as a valid alternative. The ordinal dependent variable (frequency of breast pain) was collapsed into a binary variable and all categorical independent variables were similarly collapsed, as described above, due to low frequency counts within the group levels. A binomial logistic regression was then performed to determine the effect of age (continuous numerical variable), breast size (“small breasts” or “medium-to-hypertrophic breasts”), BMI (continuous numerical variable) and frequency of sports bra use (“always” or “less than always”) on the likelihood of
participants reporting exercise-induced breast pain ("yes" or "no"). In addition to evaluating the strength of this 4-factor model in predicting the likelihood of an athlete reporting exercise-induced breast pain, the test also ascertained the association of each independent variable with the likelihood (Odds Ratio) of an athlete reporting exercise-induced breast pain. Before performing the full regression, linearity of the continuous variables (age and BMI) with respect to the logit of the dependent variable (exercise-induced breast pain) was confirmed via the Box-Tidwell procedure. All variables were also found to meet the assumption of non-multicollinearity and no significant outliers were present. Statistical analyses were performed in the Statistical Package for the Social Sciences (Version 23; SPSS Inc., Chicago, USA) with an alpha level of $p < 0.05$.

### 3.3 Results

#### 3.3.1 Participant characteristics

Four-hundred and ninety participants answered all the survey questions relevant to the current study; i.e. exercise-induced breast pain, physical characteristics and sports bra use. Forty-five percent of the participants ($n = 218$) reported experiencing exercise-induced breast pain during training or competition. Participant characteristics for the two continuous variables (age and BMI) are presented in Table 5. Participants also reported bra sizes ranging from 8A to 20G (see Appendix A for international bra sizing), with 363 of these sizes grouped into the “small breasts” category and 127 in the “medium-to-hypertrophic breasts” category. Sports bra use during training and competition was ranked as “always” by 436 participants, whereas the other 54 participants reported using a sports bra “less than always”.

42
Table 5: Mean ± standard deviation (and minimum, maximum) values of characteristics for the participants who reported exercise-induced breast pain, participants who did not report exercise-induced breast pain and all participants.

<table>
<thead>
<tr>
<th></th>
<th>Breast pain (n = 218)</th>
<th>No breast pain (n = 272)</th>
<th>All participants (n = 490)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>25.6 ± 9.8</td>
<td>26.2 ± 9.5</td>
<td>25.9 ± 9.6 (18, 71)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.7 ± 8.0</td>
<td>169.0 ± 7.9</td>
<td>168.9 ± 7.9 (140, 201)</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>66.9 ± 12.2</td>
<td>64.9 ± 9.5</td>
<td>65.8 ± 10.8 (41, 120)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.5 ± 3.9</td>
<td>22.7 ± 2.7</td>
<td>23.0 ± 3.3 (15.4, 37.9)</td>
</tr>
</tbody>
</table>

3.3.2 Regression model

The logistic regression model was statistically significant, $\chi^2(4) = 58.940$, $p < 0.001$, with the 4-factor model explaining 15.2% (Nagelkerke $R^2$) of the variance in exercise-induced breast pain and correctly classifying 66.3% of cases based on athletes who did or did not report breast pain. Sensitivity of the model was 40.8%, specificity was 86.8%, the positive predictive value was 71.2% and the negative predictive value was 64.7%. Of the four variables included in the model (age, breast size, BMI and frequency of sports bra use), only age and breast size were independently associated with a significantly higher likelihood of a participant reporting exercise-induced breast pain. Complete results of the binomial logistic regression are presented in Table 6.

Table 6: Results of the binomial logistic regression that used age, breast size, BMI and frequency of sports bra use to predict the likelihood of a participant reporting exercise-induced breast pain.

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>St Err</th>
<th>Wald $X^2$</th>
<th>df</th>
<th>$p$</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.026</td>
<td>0.011</td>
<td>5.535</td>
<td>1</td>
<td>0.019</td>
<td>1.026</td>
<td>(1.004, 1.048)</td>
</tr>
<tr>
<td>Breast size</td>
<td>1.706</td>
<td>0.261</td>
<td>42.620</td>
<td>1</td>
<td>&lt;0.001</td>
<td>5.508</td>
<td>(3.300, 9.192)</td>
</tr>
<tr>
<td>BMI</td>
<td>0.013</td>
<td>0.033</td>
<td>0.158</td>
<td>1</td>
<td>0.691</td>
<td>1.013</td>
<td>(0.950, 1.081)</td>
</tr>
<tr>
<td>Sports bra use</td>
<td>0.348</td>
<td>0.316</td>
<td>1.211</td>
<td>1</td>
<td>0.271</td>
<td>1.416</td>
<td>(0.762, 2.629)</td>
</tr>
</tbody>
</table>

OR: Odds Ratio
Age: For every 1-year increase in athlete age, there was a significant 2.6% increase in the likelihood of a participant reporting that she experienced exercise-induced breast pain.

Breast size: Participants with “medium-to-hypertrophic breasts” were significantly more likely (5.5 times) to report experiencing exercise-induced breast pain than participants with “small breasts” (see Figure 3).

BMI: For every 1 kg/m² increase in BMI, there was a non-significant 1.3% increase in the likelihood of a participant experiencing exercise-induced breast pain.

Frequency of sports bra use: Although participants who reported wearing a sports bra “less than always” (11%) during training and competition were 1.4 times more likely to experience exercise-induced breast pain than participants who reported “always” using a sports bra, the relationship was not statistically significant.

Figure 3: Percentage of participants with “small breasts” and with “medium to hypertrophic breasts” who did report or did not report exercise-induced breast pain.

3.4 Discussion

This is the first study to investigate whether self-reported physical characteristics and sports bra use of elite female athletes across a range of sports could be used to predict exercise-induced breast pain in this population. The binomial logistic regression model
Breast pain model

using age, breast size, BMI and frequency of sports bra use correctly classified 66% of athletes based on whether they did or did not report exercise-induced breast pain. Although statistically significant as predicted in H1, the model was only able to explain 15.2% of the overall variability in reported breast pain and was therefore considered to be weak. The model also had higher specificity than sensitivity, such that the model was more successful in correctly classifying participants who did not report breast pain as not having breast pain (true negatives) than correctly classifying athletes who did report breast pain as having breast pain (true positives). This further detracts from the clinical usefulness of the model, as it was found to greatly underestimate the number of participants who did report breast pain. This error in the model might lead coaches and clinicians associated with female athletes to wrongly conclude that a particular athlete was not at risk when she was indeed experiencing breast pain during training and competition.

Consistent with the second hypothesis, age was significantly associated with a higher likelihood of elite female athletes reporting exercise-induced breast pain. In fact, there was a 26% increase in the likelihood of the participants reporting exercise-induced breast pain for every 10 years increase in age. This increase in reported breast pain is attributed to age-related changes in the mechanical properties of the anatomical breast supports, as has been observed in breast skin (Coltman et al. 2017c), thus reducing the level of intrinsic breast support. Older athletes are therefore likely to require a higher level of breast support to manage exercise-induced breast pain compared to their younger counterparts.

Breast size also had a statistically significant association with exercise-induced breast pain, whereby athletes with medium-to-hypertrophic breasts were 5.5 times more likely to report exercise-induced breast pain than athletes with small breasts. Breast size
Breast pain model

was therefore an important predictor of breast pain, which is consistent with previous research involving the general female population (Bridgman et al. 2010; Brown et al. 2014a; Lorentzen and Lawson 1987). Furthermore, 26% of participants in this study had medium, large or hypertrophic breasts, with the largest participant bra sizes equating to more than 1.2 litres of volume per breast (Coltman et al. 2014). These results confirm that elite female athletes have a wide range of breast sizes. However, the variable of breast size used in this regression model relied on self-reported bra sizes, which is a limitation of the current study considering that 85–100% of women are reportedly wearing the incorrect bra size (Coltman et al. 2018b; Greenbaum et al. 2003; McGhee and Steele 2006; McGhee and Steele 2010b). Breast volume was estimated based on these bra sizes and participants were collapsed into only two breast size groups due to low numbers in these larger breast size categorised (i.e. medium breasts, large breasts and hypertrophic breasts were all grouped into a single category). Breast sizes within these three groups, however, can differ by more than one litre of volume (Coltman et al. 2017b). Based on these findings, it is recommended that future researchers should directly measure breast size using quantitative techniques, such as three-dimensional scanning (Coltman et al. 2017a), and recruit a larger cohort of athletes with medium, large and hypertrophic breasts.

In contrast to the second and third hypotheses, there were no significant relationships between BMI or frequency of sports bra use and the likelihood of an athlete reporting exercise-induced breast pain. A possible explanation for these results is that higher BMI values in elite female athletes are likely due to increased muscle mass rather than increased fat mass (Garrido-Chamorro et al. 2009). Therefore, the association between BMI and breast size that has been reported in the general population might not hold true for elite female athletes. This suggests that body fat percentage rather than BMI
might be a better variable to predict exercise-induced breast pain in elite female athletes. More frequent sports bra use was also not associated with a lower likelihood of reporting breast pain, a result that was in apparent contrast to previous research (Lorentzen and Lawson 1987; McGhee et al. 2010b; Scurr et al. 2010). However, a sports bra must be well-fitted and well-designed in order to function correctly and provide adequate support for women while they participate in physical activity (McGhee and Steele 2010b). Therefore, an ill-fitting, low support sports bra worn during every training session is unlikely to provide an appropriate level of breast support for most athletes, particularly those with large breasts. It is therefore recommended that future predictive models for exercise-induced breast pain incorporate a measure of bra fit or breast support, as these variables might be more strongly associated with exercise-induced breast pain than only the frequency of sports bra use.

The specific model used in this study highlighted the effects of age and breast size on exercise-induced breast pain and the increased need for appropriate breast support in older athletes and those with large breasts. The variables used in this model (age, breast size, BMI and sports bra use) were chosen based on previous research that suggested a strong association between these factors and breast pain (Brown et al. 2014a; Coltman et al. 2017b; Coltman et al. 2017c; Scurr et al. 2010). It is important to acknowledge, however, that breast pain is multifactorial (Brown et al. 2014b; Burbage and Cameron 2017; McGhee and Steele 2010a). Therefore, other factors, such as duration of activity and bra characteristics, also have the potential to contribute to exercise-induced breast pain (see Chapter 2, Section 2.4.2). Future research is encouraged to investigate whether variables such as age, a direct measure of breast size (e.g. three-dimensional scanning), a direct measure of body composition (e.g. body fat percentage), bra fit/breast support level, a valid measure of training volume and other relevant factors can add strength to the
Breast pain model

model and, therefore, be used by coaches and clinicians to predict exercise-induced breast pain in elite female athletes. As the current model was also limited by the necessary transformation of ordinal data to binary data due to low frequency counts, future research is also encouraged to recruit a larger sample size.

3.5 Conclusion

Increased age and larger breast size were significantly associated with an increased likelihood of elite female athletes reporting exercise-induced breast pain. However, despite being statistically significant, the regression model using age, breast size, BMI and frequency of sports bra use could only weakly predict which athletes did or did not report exercise-induced breast pain. The model therefore requires substantial improvement in its predictive strength before it can serve as a useful tool for coaches and clinicians to identify female athletes who may be susceptible to exercise-induced breast pain.
Part II

Breast injuries in elite female athletes
Chapter 4

The occurrence, causes and perceived performance effects of breast injuries in elite female athletes


Abstract

Female breasts are vulnerable to direct blows or skin injuries during sport; however, little research has investigated breast injuries experienced by female athletes. This study aimed to investigate the occurrence, causes and perceived performance effects of breast injuries in elite female athletes. A custom-designed survey about breast injury and associated performance effects was distributed to female athletes aged over 18 years who were competing nationally or internationally in their chosen sport. Five hundred and four female elite female athletes from 46 different sports completed the survey. Thirty-six percent of participants (n = 182) reported sustaining a breast injury and 21% (n = 37) perceived that their breast injury negatively affected their performance. Contact breast injuries were reported by significantly more athletes involved in contact or combat sports and by athletes with larger breasts or a higher BMI. Frictional breast injuries were reported by significantly more older athletes or those with larger breasts. Less than 10% of participants reported their breast injury to a coach or medical professional, and only half reported using any prevention strategies. Evidence-based breast injury prevention and management strategies are needed to decrease the overall occurrence and negative performance effects of breast injuries in elite female athletes.
4.1 Introduction

Due to their location on the anterior chest wall, limited anatomical support and lack of musculoskeletal protection, female breasts are vulnerable to injury, particularly from direct blows during contact sports (see Chapter 1, Section 1.1.3; Greydanus et al. 1998; Jiang and Ni 2013; Loud and Micheli 2001). The extensive superficial capillary networks within breasts also increase the likelihood of contusions and haematomas from direct contact (Haycock 1987). Despite this vulnerability to injury, there is a paucity of published research investigating breast injuries sustained during sport. One of the few published studies in this field was a survey completed by athletic training staff of injuries sustained by female collegiate athletes in 1975, which revealed that breast injuries were the least common injury for this cohort (Gillette 1975). Possibly because breast injuries were not considered problematic in this study, injuries to the breast or chest have seldom since been included in research that has documented injuries sustained by female athletes (Hägglund et al. 2009; Hilibrand et al. 2015; Langeveld et al. 2012; McCarthy et al. 2013; Peck et al. 2013; Zelisko et al. 1982).

In sports injury research, investigators traditionally record injuries that have been reported by athletes to coaches or athletic trainers (Dönmez et al. 2018; Gillette 1975; Schiff et al. 2010) or that have been diagnosed by team physiotherapists or physicians (Giza et al. 2005; Peck et al. 2013; Wik et al. 2019). These methods of recording sports injuries, however, are unlikely to capture reliable information on breast injuries because female athletes are often reluctant to report injuries they sustain to their breasts or chests (Smith et al. 2018), particularly to male athletic staff (Drummond et al. 2007). Furthermore, there is no widely accepted medical classification for breast injuries sustained during sport and no information about breast injuries was included in the most recent iteration of the Team Physician Consensus Statement on Female Athlete Issues, a
publication specifically designed to educate team doctors about injuries which female athletes might sustain (2018). This suggests that directly surveying athletes may be a more reliable method of recording these sensitive and unclassified breast injuries.

Most sports injury researchers also use a narrow definition of injury (Clarsen and Bahr 2014), recording only injuries that result in time-loss from training or matches (Dönmez et al. 2018; Engström et al. 1991; Schick et al. 2008) or injuries that necessitate medical attention (Giza et al. 2005; Holland et al. 2018; Peck et al. 2013). It is unknown, however, whether breast injuries are severe enough to remove an athlete from sport or require medical attention, or whether female athletes even seek medical attention for their breast injuries. It is therefore possible that a narrow definition of a sports injury might systematically exclude breast injuries from being recorded, even though these injuries could negatively affect sporting performance. To better understand the scope of breast injuries sustained in sport and whether these injuries affect performance, it is necessary to utilise an “any physical complaint” injury definition (Clarsen and Bahr 2014) and record all occurrences of breast injuries during sport, irrespective of severity.

A 2018 survey of female collegiate athletes revealed that breast injuries affected nearly 48% of collegiate basketball, soccer, softball and volleyball athletes in America (Smith et al. 2018). Only 10% of female athletes in this study reported their breast injuries to medical personnel (Smith et al. 2018), which supports the notion that breast injuries are likely to have been under-represented in previous sports injury research. This study also broadly classified breasts injuries as any trauma to the breast including contusions, bruising, hematomas, oedema and pain (Smith et al. 2018), irrespective of time-loss or medical attention, which might explain the higher prevalence of injuries recorded in this study compared to the 1975 survey study (Gillette 1975). Although this 2018 study revealed that nearly half of the female athletes had sustained a breast injury during sport,
Breast injury in elite athletes

the participants only included college-aged basketball, soccer, softball and volleyball players. Given the wide variety of sports that female athletes participate in (see Chapter 2, Section 2.3.1) and the growing popularity of contact sport (Huxley 2016; Navaratnam 2017; Roberts 2017; Rugby Australia 2018), there is a need to investigate the occurrence, causes and perceived performance effects of breast injuries sustained across a greater diversity of sports.

In addition to the breasts being vulnerable to trauma, skin around the upper torso and breast is also sensitive to potential injury from repetitive contact with an athlete’s sports bra or uniform, which might result in chafing or lacerations from rigid bra components (Haycock 1987; Loud and Micheli 2001). “Runner’s nipple” (also known as “jogger’s nipple”) is a chafing injury that has been extensively reported in both female and male runners, the occurrence of which has been associated with running distance (Purim and Leite 2014), body mass index (BMI; Helm et al. 2012) and infrequent sports bra use in female athletes (Mailler and Adams 2004). It is therefore possible that female athletes who train for several hours, have a higher BMI or use a sports bra less frequently might be susceptible to frictional breast injuries. Larger breast size might also contribute to frictional breast injuries in female athletes, because overweight men have been found to sustain frequent chafing injuries due to increased “jiggling” of breast tissue and a resultant increase in friction between the breast and their shirt (Helm et al. 2012).

Although numerous studies have investigated chafing injuries in runners (Adams 2002; Loud and Micheli 2001; Mailler and Adams 2004; Mailler-Savage and Adams 2006), no research was located that specifically investigated chafing injuries across a range of sports or how these injuries might affect sporting performance.

This study aimed to investigate, through a direct survey and the use of a broad injury definition: (i) the occurrence and causes of breast injuries reported by elite female
athletes from a wide range of sports and (ii) whether the athletes perceived these breast injuries to affect their sporting performance. Based on the current literature, it was hypothesised that:

- **H1**: elite female athletes would experience breast injuries during sport;

- **H2**: breast injuries would be caused by direct contact or friction between breast skin and an athlete’s bra or uniform during sport; and

- **H3**: elite female athletes would perceive that breast injuries negatively affected their sporting performance.

### 4.2 Design and methods

#### 4.2.1 Survey design and implementation

Although sports injury research traditionally relies on surveillance by coaches or medical staff, the sensitive nature of breast injuries, the absence of standardised breast injury definitions and the lack of breast injury reporting necessitated a survey to directly ask female athletes about the occurrence, causes and performance effects of breast injuries. An anonymous 42-question survey was therefore designed to gather data on breast issues sustained by female athletes, aged 18 years or older, currently competing nationally or internationally (i.e. representing their state or country) in any sport. The survey design, recruitment and study approval procedures were the same as those listed in Chapter 2.2.1 and 2.2.2. In brief, athletes satisfying the above inclusion criteria were indirectly recruited to participate by contacting coaches, administrators and medical staff associated with female sports, who could then elect to share the study details with their athletes. Participants were also consistent with those reported in Section 2.3.1, although data from participants who did not answer all questions relevant to the current study were excluded from the analysis (see Section 4.3.1 below).
4.2.2 Analytical variables

Age: Participants recorded their date of birth, which was then used to calculate their age at the date they completed the survey. Age was recorded as a continuous numerical variable.

Breast size: Participants were asked to report the band size and cup size (e.g. 8B, 32DD) that they most often wore, which was then used to estimate each participant’s breast size from a previously developed reference table (see Table 4). The full details are provided in Chapter 3, Section 3.2.2. These ordinal breast size scores were then treated as continuous numerical data, whereby a score closer to “1” represented a smaller mean breast size and a score closer to “4” represented a larger mean breast size.

Body mass index: Participants reported their estimated height in centimetres and body mass in kilograms. Each participant’s body mass index (BMI) was then calculated by dividing her mass by her height, squared (kg/m²). BMI was represented as a continuous numerical variable.

Frequency of sports bra use: The participants were asked how frequently they wore any form of sports bra (either a compression crop top, an encapsulation sports bra or a “hybrid” combination of an encapsulation bra with a compressive outer layer) during training and competition on a five-point Likert scale ranging from “always” (score = 1) to “never” (score = 5). These ordinal scores were treated as continuous numerical data, whereby a score closer to “1” represented a higher mean frequency of sports bra use and a score closer to “5” represented a lower mean frequency of sports bra use.

Weekly training: Participants were asked to estimate their weekly in-season training hours. Where a range of numbers was given, an average was calculated to produce a continuous numerical variable.
**Sport type:** The participants recorded their sport and position/event. This response was then used to classify each participant into one of three sports categories: (i) “contact sports” – in which contact between players is an inherent aspect of the sport (e.g. contact football codes), (ii) “combat sports” – in which athletes engage in one-on-one combat with an opponent and contact is an inherent aspect of the sport (e.g. boxing, taekwondo), and (iii) “non-contact sports” – in which extensive contact between players does not usually occur (e.g. running, swimming). Due to a high frequency count of “non-contact sports”, the categories “contact sports” and “combat sports” were later combined into a single group (“contact/combat sports”) for analysis. Sport type was therefore represented as a dichotomous independent variable (“contact/combat sports” and “non-contact sports”).

**Occurrence of breast injuries:** Participants were asked “Have you ever had a breast injury during training or competition (e.g. a bruise to your breast from a direct blow, a cut from a piece of sporting equipment, a scrape, chafing of the nipples, etc.)?”, to which they could respond either “yes” or “no”.

**Causes of breast injuries:** If a participant answered “yes” to ever having a breast injury, she was also asked to specify which cause(s) of injury she had experienced. Options (developed through the focus groups) were: “direct blow from another athlete (e.g. elbowed/kicked in the chest)”; “direct blow from sporting equipment (e.g. soccer ball, hockey stick, etc.)”; “direct contact with a surface (e.g. falling onto chest)”; and “contact from my sports bra/uniform (e.g. chafing of nipples, cut from underwire, etc.)”. The former three responses (another athlete, sporting equipment and surface) were grouped together as “contact breast injuries” and the response “sports bra/uniform” was considered a “frictional breast injury”.

56
Breast injury in elite athletes

**Perceived performance effects:** Participants were asked whether breast injuries had a perceived negative effect on their sporting performance during training or competition, with possible responses “yes” or “no”.

**Injury reporting:** Participants were asked whether they consulted anyone about their breast injury, with the response options being: “parent”; “team mate”; “coach”; “doctor”; “physiotherapist”; “sport scientist”; “I did not seek advice about the injury”; or “other”, where space was given to write a free response. Responses of reporting to a coach, doctor, physiotherapist or sport scientist were grouped collectively as “coach or medical professional”.

**Prevention strategies:** The participants were asked to select all breast injury prevention strategies that they used. Response options were developed through focus groups and included “wear a padded sports bra”; “wear a protective bra”; “strap my breasts to my chest using tape or bandages”; “modify my movements to prevent breast injury”; “limit activities that might cause breast injury”; “protect my breasts with my hands during sport”; “I do not use any strategies to prevent breast injury”; and “other”, where space was given to write a free response. Participants were also asked to report whether they had ever used breast protective equipment, with responses “yes” or “no”.

4.2.3 **Statistical analyses**

**Descriptive statistics:** Basic frequency counts were used to calculate the overall percentage of participants who reported experiencing any breast injuries, contact breast injuries and frictional breast injuries, as well as the percentage of participants who reported that their breast injury had a negative effect on their sporting performance. Data were also reported for the percentage of participants who used various breast injury prevention strategies and those who reported their breast injury.
Chi-squared Test of Independence: The SPSS Crosstabs procedure was used to generate a contingency table, summarising the distribution of participants in this study who reported that they had experienced breast injuries in each sport type (“contact/combat sports” and “non-contact sports”). Statistical significance of the relationship between sport type and breast injury (“yes” or “no”) was assessed using a Chi-squared Test of Independence.

Mann-Whitney U-test: A series of Mann-Whitney U-tests was used to compare participants who did and did not report: (i) any breast injuries, (ii) contact breast injuries and (iii) frictional breast injuries, classified by age, BMI, breast size, frequency of sports bra use and average weekly training hours. This test was chosen as a non-parametric alternative to an independent samples t-test and for its robustness with regard to significant outliers in the data. Although multiple statistical tests were conducted, increasing the chance of incurring an error, no adjustment to the alpha level was deemed necessary given the exploratory nature of the study and the low cost associated with incurring an error (Sinclair et al. 2013). Differences in the mean rank between groups were considered statistically significant at $p < 0.05$. All statistics were performed in the Statistical Package for the Social Sciences (Version 23; SPSS Inc., Chicago, USA).

4.3 Results

4.3.1 Participants

Five hundred and four female athletes (mean age 25.7 ± 9.5 years; height 168.7 ± 8.0 cm; body mass 65.6 ± 10.8 kg; BMI 23.0 ± 3.3 kg/m$^2$) competing in 46 different sports (see Figure 4) completed the survey. Participants reported bra sizes ranging from 8A to 20G (Australian bra sizing; see Appendix A for international bra sizing) and mean weekly training hours of 12.1 ± 8.4 hours. Ninety percent of participants reported always wearing a sports bra during training and competition.
4.3.2 Occurrence of breast injuries

Breast injuries were reported by 36% (n = 182) of the participants. Only 10% of these participants (n = 18) reported their breast injury to a coach or medical professional (i.e. a doctor, physiotherapist or sports scientist).

4.3.3 Causes of breast injuries

Participants reported that breast injuries were caused by direct contact with another athlete, with sporting equipment or with the ground (contact breast injury; reported by 29% of participants) or by friction from a bra or uniform rubbing or chafing the skin of their breasts (frictional breast injury; reported by 20% of participants). There was a statistically significant association between sport type and both the occurrence of any breast injuries and the occurrence of contact breast injuries. That is, a significantly greater percentage of participants from contact/combat sports reported any breast injuries ($\chi^2(1) = 5.975$) and contact breast injuries ($\chi^2(1) = 12.715$; see Table 7) compared to participants from non-contact sports.
Table 7: Percentage of participants from non-contact sports and contact/combat sports who reported contact breast injuries, frictional breast injuries and any breast injuries.

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Non-contact sports (n = 413)</th>
<th>Contact/combat sports (n = 91)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact breast injury</td>
<td>25.6</td>
<td>44.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Frictional breast injury</td>
<td>20.0</td>
<td>21.1</td>
<td>0.456</td>
</tr>
<tr>
<td>Any breast injury</td>
<td>33.7</td>
<td>47.3</td>
<td>0.011</td>
</tr>
</tbody>
</table>

As shown in Figure 5, contact breast injuries were also significantly associated with breast size and BMI, whereby participants who experienced contact breast injuries had larger breasts and a higher BMI compared to participants who did not experience contact breast injuries. In contrast, frictional breast injuries were significantly associated with age and breast size, whereby participants who experienced frictional breast injuries were older and had larger breasts compared to participants who did not experience frictional breast injuries (see Figure 6).
Figure 5: The frequency distribution of (A) age, (B) breast size\(^a\), (C) BMI, (D) frequency of sports bra use\(^b\), and (E) weekly training for participants who did not report (no injury) and did report (injury) contact breast injuries.

\(^a\) Breast size ranked from 1 (small breasts, <350 ml per breast) to 4 (hypertrophic breasts, >1200 ml per breast)

\(^b\) Frequency of sports bra use ranked from 1 (always) to 5 (never)

\(*\) indicates significant difference (\(p < 0.05\)) between participants who did not report and did report contact breast injuries.
Breast injury in elite athletes

Figure 6: The frequency distribution of (A) age, (B) breast size\(^a\), (C) BMI, (D) frequency of sports bra use\(^b\), and (E) weekly training for participants who did not report (no injury) and did report (injury) frictional breast injuries.

\(^a\) Breast size ranked from 1 (small breasts, <350 ml per breast) to 4 (hypertrophic breasts, >1200 ml per breast)

\(^b\) Frequency of sports bra use ranked from 1 (always) to 5 (never)

\(^*\) indicates significant difference (\(p < 0.05\)) between participants who did not report and did report frictional breast injuries.
4.3.4 Perceived performance effects of breast injuries

Twenty one percent (n = 37) of the participants who reported previously experiencing a breast injury also reported that they perceived their breast injury to negatively affect their sporting performance. Across all sports, 43% of participants (n = 76) reported that they had no breast injury prevention strategies and only 3% of participants (n = 14) reported wearing any breast padding during training or competition. Thirteen of these participants played combat sports in which breast padding was either mandatory or actively encouraged (e.g. boxing and fencing) and one played ice hockey. Other injury prevention strategies used by participants who reported experiencing breast injuries (n = 182) included wearing a sports bra (29%), modifying their movements to prevent injury (e.g. altering running style; 9%), limiting specific activities that might result in injury (e.g. avoiding a tackle; 6%), physically placing their hands in front of their breasts to prevent injury (6%) or strapping or bandaging their breasts (3%).

4.4 Discussion

This is the first study to specifically investigate the occurrence, causes and perceived performance effects of breast injuries in elite female athletes across a wide range of sports. More than one in three of these elite athletes reported experiencing an injury to their breasts during training or competition. Despite 21% of the participants perceiving that these breast injuries negatively affected their sporting performance, very few participants reported their injury to a coach or medical professional and only a few participants reported using any breast injury prevention strategy. The implications of these unique findings are discussed below.

4.4.1 Occurrence of breast injuries

As hypothesised (H1), elite female athletes (36%) reported experiencing breast injuries during their sport. Although this finding was in contrast to previous research that reported
breast injuries as an uncommon injury for female athletes (Gillette 1975), it was somewhat consistent with recent findings that reported a high occurrence (48%) of breast injuries among female basketball, soccer, softball and volleyball athletes in America (Smith et al. 2018). These data highlight the need to directly and specifically ask athletes about their experience with breast injuries, rather than assuming that all injuries will be reported to athletic or medical staff. Indeed, 90% of participants in the current survey indicated that they did not report their breast injury to a coach or medical professional. Similarly, the 2018 survey of American collegiate athletes found that very few athletes reported their breast injuries (Smith et al. 2018). These findings support the notion that breast injuries are likely to have been under-represented in previous sports injury research (Gillette 1975) due to infrequent reporting by athletes. This incorrect assumption related to a low occurrence of breast injuries in sport is likely to have contributed, in turn, to a general lack of breast injury awareness amongst coaches, medical professionals and the athletes themselves. As more than one in three participants reported sustaining a breast injury, it is crucial that athletes, coaches and medical professionals associated with women’s teams are educated about the risk of athletes incurring a breast injury during training or competition to increase overall awareness so that athletes can be encouraged to report and receive treatment for these injuries.

4.4.2 Causes of breast injuries

Consistent with the second hypothesis (H2), two main types of breast injuries were self-reported by the participants: (i) contact breast injuries, caused by a direct blow from another athlete, a piece of equipment or the ground, and (ii) frictional breast injuries. Although some medical professionals have reported observing contact injuries to the breast (Haycock 1987), this is the first study to report on the specific causes of these contact breast injuries in a diverse cohort of elite female athletes. A greater occurrence of
contact injuries was reported compared to frictional injuries and these injuries were primarily related to direct contact with another athlete. Unsurprisingly, significantly more contact/combat athletes reported contact breast injuries compared to non-contact athletes, supporting the assertion made by Haycock that “traumatic” breast injuries are more common in contact sports (Haycock 1987). As female participation numbers rise in sports such as Australian Rules Football (AFL), Rugby League and Rugby Union (Huxley 2016; Roberts 2017), an increasing number of athletes are likely to incur contact breast injuries. Therefore, strategies to prevent and manage contact breast injuries in the contact football codes are likely to be necessary.

Participants who experienced contact breast injuries also had larger breasts, on average, compared to participants who did not experience contact breast injuries. This association is likely because larger breasts have a greater surface area for potential contact and they usually protrude farther from the chest wall, increasing their vulnerability to direct contact. Additionally, BMI was significantly associated with contact breast injuries, such that participants who reported contact breast injuries had a higher BMI compared to participants who did not report contact breast injuries. As BMI is closely associated with breast size in the general female population (Brown et al. 2012; Coltman et al. 2017b), it is likely that the greater susceptibility to contact breast injuries in participants with a larger BMI is partially due to their larger breast size. Therefore, strategies to prevent and manage contact breast injury should be developed specifically for athletes from contact and combat sports, as well as athletes with a larger BMI or larger breasts. Given the wide range of physical characteristics reported by participants who sustained contact injuries, however, prevention strategies must also be developed to cater for a diverse range of elite female athletes, not only those with larger breasts.
Previous research has documented long-distance runners reporting specific chafing injuries such as “runner’s nipple” (Helm et al. 2012; Mailler-Savage and Adams 2006; Purim and Leite 2014). However, this was the first study to report that elite female athletes from a wide variety of sports, and not just long-distance runners, experience lacerations or chafing caused by frictional forces generated between their sports bra or uniform and breast skin. Although no significant difference was found between participants who did and did not report frictional breast injuries in terms of training hours, BMI or frequency of sports bra use, participants who reported experiencing frictional breast injuries had significantly larger breasts than participants who did not report frictional breast injuries. This finding is consistent with previous breast biomechanics research that has associated larger breast mass with greater three-dimensional breast motion (Lorentzen and Lawson 1987; McGhee et al. 2013; Wood et al. 2012), which is, in turn, likely to increase friction between the breast skin and the sports bra.

Participants who reported frictional breast injuries were also significantly older than participants who did not report frictional breast injuries. This finding is attributed to the age-related changes in skin elasticity that have been observed in the breast and chest skin after the age of 25 years (Coltman et al. 2017c). These skin changes substantially reduce anatomical support to the breasts, permitting greater breast motion and, in turn, increased friction between the breast skin and the bra. Breast skin thickness also decreases with ageing (Coltman et al. 2017c), which might make older breasts more vulnerable to chafing and lacerations. Frictional breast injuries were reported by many elite female athletes (20%) in this study. It is therefore crucial that athletes, coaches and medical professionals receive education about frictional breast injuries and that evidence-based strategies are developed to prevent and manage these injuries, with special consideration for older athletes and those with larger breasts. However, as participants who reported
frictional breast injuries were diverse in terms of age, breast size and BMI, it is imperative that any future prevention or management strategies cater for the variety of female athletes who sustain frictional injuries rather than just those who reported a higher occurrence of these injuries.

4.4.3 Perceived performance effects of breast injuries

In support of the third hypothesis (H3), approximately one in five of the participants who experienced a breast injury perceived that their breast injury negatively affected their sporting performance. These findings are also consistent with the survey of American collegiate female athletes, which found that 18% of basketball, soccer, softball and volleyball players reported decreases in their sports performance or participation as a result of their breast injury (Smith et al. 2018). It is therefore imperative that athletes, coaches and medical professionals are aware of the potential for breast injuries to hinder sporting performance and that conversations around breast injuries are normalised in female sport.

Despite the potential negative effects of breast injuries on sporting performance, nearly half of the participants in this study reported that they had no strategies to prevent breast injuries. Of the strategies that were used, numerous participants reported modifying the way they ran/played or limiting specific activities (e.g. avoided a tackle) as their primary means of preventing breast injuries. Several participants also stated that they physically placed their hands in front of their breasts while playing to avoid contact breast injuries. Regardless of how effective or ineffective these actions might be in preventing a breast injury, it is likely that many of these strategies could further impede sporting performance, either due to being distracting or contributing to improper technique. Development of viable, evidence-based strategies to prevent breast injuries occurring is therefore critical. However, before any recommendations can be made with regard to
specific injury prevention strategies, further research is needed to understand the reasons why athletes choose to or choose not to use existing strategies that could prevent breast injuries in sport (O’Brien et al. 2019). It is also necessary to investigate the attitudes and suggestions of coaches and medical professionals with respect to breast injury prevention strategies because these staff will be critical in the successful implementation of any future breast injury prevention or management strategies (O’Brien et al. 2019).

4.4.4 Study limitations

As the results of the present study are based on data collected from a survey, it is necessary to acknowledge the inherent limitations associated with subjective, self-reported data such as breast size, BMI and frequency of sports bra use. Directly assessing participant characteristics, specifically breast characteristics, and quantifying other factors that might be associated with breast injuries, such as bra fit, is therefore recommended for future research in this field. Due to the exploratory nature of this research, several relevant follow-up questions (e.g. how breast injuries are perceived to affect performance) were not anticipated. Therefore, additional research is also encouraged to further explore the causes of breast injuries in different cohorts of female athletes and how these injuries affect performance.

4.5 Conclusion

Over one-third of elite female athletes reported experiencing either contact or frictional breast injuries during sport. Despite many of these elite athletes perceiving breast injuries to negatively affect their sporting performance, only 10% had ever reported their breast injury to a coach or medical professional. It is therefore imperative that athletes, coaches and medical professionals associated with women’s sport are made aware of the occurrence and potential negative effects of breast injuries. It is critical to normalise conversations around breast health so that athletes can be encouraged to report and, when
necessary, receive treatment for these injuries. Further research is also required to better understand factors that affect breast injuries in sport in order to develop effective evidence-based breast injury prevention strategies, particularly for female contact football players.
Part III

Current breast injury & prevention situation in contact football
Chapter 5

Breast injuries reported by female contact football players based on football code, player position and competition level

This chapter is an amended version of the published manuscript: Brisbane BR, Steele JR, Phillips EJ and McGhee DE. Breast injuries reported by female contact football players based on football code, player position and competition level. Science and Medicine in Football. 2019;4(2):1-8. doi:10.1080/24733938.2019.1682184

Abstract

Female athletes involved in contact sports are sustaining injuries to their breasts. This study aimed to investigate the occurrence, causes and perceived performance effects of contact breast injuries reported by females participating in contact football by code, player position and competition level. The awareness and perceptions of these injuries by staff associated with female contact football teams was also examined. Two hundred and ninety-seven female Australian Football (AFL), Rugby League, Rugby Union (XVs) and Rugby 7s players completed a custom-design player survey about contact breast injuries. Fifty-eight percent of players reported ever experiencing a contact breast injury and 48% perceived that their injury affected their football performance. Two hundred and forty-two coaches and medical professionals also completed a custom-designed staff survey. Despite the high occurrence of contact breast injuries reported by players, half of the coaches and medical professionals surveyed were not aware that breast injuries were a problem for female contact football players. Athletes, coaches and medical professionals involved in female contact football may benefit from education on the potential for, and the effects of, contact breast injuries so that these injuries can be better prevented and managed.
5.1 Introduction

Female participation in the contact football codes is dramatically increasing (Navaratnam 2017; Rugby Australia 2018), and therefore it is necessary to investigate potentially unique injuries experienced by female contact football players. One specific consideration is contact breast injuries, which have been reported to affect 44% of female athletes involved in contact/combat sports (e.g. the football codes and martial arts; see Chapter 4, Section 4.3.3). Although this percentage suggests that breast injuries are problematic for female contact football players, the data were derived for female athletes from 49 different sports and did not investigate contact football players independently of combat athletes. Furthermore, the study did not specifically evaluate “the current injury situation”, as recommended by the first phase of the Team-sport Injury Prevention framework (O’Brien et al. 2019). Therefore, the occurrence, causes and perceived performance effects of breast injuries in female contact football players, as well as the perceptions of players, coaches and other staff members towards breast injury occurrence, remains unknown. Given the perceived negative performance effects associated with sustaining a breast injury that were reported in Chapter 4, it is imperative to thoroughly investigate factors related to the occurrence and causes of contact breast injuries in these athletes and the perceptions of breast injuries by coaches and medical professionals. Such an understanding will inform further research into the incidence and mechanisms of contact breast injury (Phase Two, TIP) and guide the future development of evidence-based prevention and management strategies (Phase Three, TIP; O’Brien et al. 2019).

The four main contact football codes played by women in Australia include Australian Rules Football (AFL), Rugby League, Rugby Union (XVs) and Rugby 7s. The rules and structure of each code vary in ways that are likely to affect the potential for players to sustain contact breast injuries. For example, AFL is played on an oval that is
Breast injury in contact football

approximately twice the size of a standard Rugby Union or Rugby League field. As such, AFL players typically run about twice the distance (Coutts et al. 2010; Cummins et al. 2013; Cunniffe et al. 2009; Waldron et al. 2011; Wisbey et al. 2010) but sustain substantially less player-to-player contact than players from other contact football codes (Gray and Jenkins 2010; Orchard and Seward 2009). In 2017, the AFL Women’s (AFLW) competition debuted with 16 players per side and a 60-minute match length (Australian Football League Commission 2019), although community-level AFL is typically played with 18 players. In contrast, women’s Rugby League includes 13 players per side over a 60-minute match and Rugby Union (XVs), which involves more tackling than either AFL or Rugby League (Gray and Jenkins 2010; Orchard and Seward 2009), includes 15 players per side during an 80-minute match. Reduced-format Rugby Union (Rugby 7s) has only 7 players per side in high-intensity 14-minute matches (World Rugby 2018).

These differences in game format affect factors such as exposure (duration of game), density of players on a field and the skills involved in the game. These factors might, in turn, affect contact breast injuries, although this notion has never been investigated.

Player positions in Rugby League, Rugby Union and Rugby 7s can be broadly categorised as “forwards” (players who form the scrum) or “backs”, whereas positions in AFL are categorised as “forwards” (offensive players), “backs” (defensive players) and “midfielders” (players who transition the ball from defence to attack). As the role of each player position varies, the occurrence and causes of breast injuries might also differ among player positions in the Rugby codes and in AFL. For example, female Rugby Union (XVs) backs sustain substantially more impacts than forwards (Suarez-Arrones et al. 2014), which might result in more contact breast injuries. This finding, however, was in contrast to research investigating male Rugby Union (XVs) (Cunniffe et al. 2009; Roberts et al. 2008) and Rugby League (Gabbett 2007; Gissane et al. 2001) players, which
revealed that forwards sustained more collisions and tackles compared to other player positions. In the AFLW, female midfielder players are involved in the most tackles relative to forwards or backs (Clarke et al. 2018). No research, however, has investigated whether the occurrence of breast injuries varies between player positions in the football codes.

Level of playing competition could also affect the occurrence of breast injuries. For example, male elite, professional and senior Australian Football (Gabbe et al. 2002; Seward et al. 1993), Rugby League (Gabbett 2004) and Rugby Union (Garraway et al. 2000) players sustain more overall injuries than their sub-elite, semi-professional and junior counterparts. Elite male Rugby League players have also been found to tackle more frequently than sub-elite players, which increases the likelihood of general injury (Gabbett et al. 2007; Gabbett et al. 2010). However, no studies were identified that investigated whether the occurrence of contact breast injuries sustained by female contact football players varied across levels of competition.

Two recent surveys revealed that only 10% of female athletes across a range of sports reported their breast injuries to coaches or medical professionals (see Chapter 4, Section 4.3.2; Smith et al. 2018). The reluctance of many athletes to report breast injuries, either due to embarrassment or the belief that breast injuries are not a serious issue, is likely to have contributed to a lack of awareness amongst staff about breast injuries occurring in football codes, which might have also hindered appropriate prevention and management strategies from being implemented. Awareness of other female-specific health concerns in sport, such as the Female Athlete Triad (low energy availability, menstrual dysfunction and low bone mineral density), have been extensively studied, with numerous publications reporting low awareness of these issues by coaches (Frideres et al. 2016; Mukherjee et al. 2016; Warner et al. 2020) and medical professionals (Curry et al.
Breast injury in contact football

2015; Kroshus et al. 2015; Troy et al. 2006). No research was located, however, that investigated the awareness or perceptions of coaches and medical professionals working with female contact football teams about breast injuries sustained by their players.

This study aimed to investigate: (i) the occurrence, causes and perceived performance effects of contact breast injuries sustained by female contact football players; (ii) how the occurrence of contact breast injuries varied among football codes, player positions and competition levels; and (iii) the awareness and perceptions of coaches and medical professionals about contact breast injuries. Based on the current literature, it was hypothesised that:

H1: a high percentage of females involved in contact football would sustain contact breast injuries and perceive these injuries to negatively affect their sporting performance;

H2: football code, player position and competition level would be associated with the occurrence, causes and perceived performance effects of contact breast injuries; and

H3: coaches and medical professionals associated with female contact football teams would underestimate the occurrence and performance effects of contact breast injuries in their players.

5.2 Design and methods

5.2.1 Player survey development and implementation

Although sports injury research traditionally relies on surveillance by coaches or physicians, the sensitive nature of breast injuries and absence of accepted breast injury definitions necessitates a direct approach to investigating the breast injuries (further details provided in Chapter 4, Section 4.1). An anonymous 17-question survey was designed to gather information on the occurrence and causes of contact breast injuries
Breast injury in contact football

sustained by female AFL, Rugby League, Rugby Union (XVs) and Rugby 7s players and whether the players perceived that these injuries affected their sporting performance (a full copy of the survey is provided in Appendix C). The survey was developed based on a previous breast injury survey (see Chapter 4, Section 4.2.1), as well as through validity testing with focus groups (n = 14) of female AFL, Rugby League, Rugby Union (XVs) and Rugby 7s players. From June to December 2018, the link to an online version of the survey was distributed via email, social media posts and fliers to football clubs, sporting organisations and coaches around Australia, who could then choose to share the link to the survey with their players. On request, 139 hard-copies of the survey were also distributed at training sessions and camps for female contact football players in the states of New South Wales, Queensland and the Australian Capital Territory, Australia. Inclusion criteria were players 18+ years of age, of any playing level, with at least one season of contact football experience.

5.2.2 Staff survey development and implementation

A 7-question online survey was also developed to investigate the awareness and perceptions of breast injuries by coaches, medical professionals and other staff associated with female contact football teams (a full copy of the survey is provided in Appendix D). The Rugby League Research Committee provided feedback on the survey to ensure that appropriate sport-specific language was used. An anonymous link to the survey was emailed to more than 450 coaches, development officers, team doctors and physiotherapists throughout Australia, who were also encouraged to share the study information with their colleagues.

The University of Wollongong Human Research Ethics Committee (HREC 2017/009) and the Australian Institute of Sport Ethics Committee (20170610) approved the design and implementation procedures of both surveys. This research was also
endorsed by the Chief Medical Officers of the Australian Football League and Rugby Australia (Rugby Union); the National Rugby League Research Committee; and World Rugby (Rugby Union and Rugby 7s).

5.2.3 Analytical variables

Occurrence and causes of contact breast injuries: Players were asked whether they had ever experienced a contact breast injury during training or a match that was caused by direct contact with another player (e.g. elbowed in the chest), sporting equipment (e.g. hit by the ball), the ground (e.g. falling onto the chest) or “none of these” (i.e. never had a contact breast injury). A contact breast injury was defined as a soft tissue injury to the breast such as a haematoma or bruise. A positive response to any of the injury scenarios was recorded as the player having experienced a contact breast injury.

Perceived performance effects: Those players who reported experiencing a contact breast injury were asked whether or not they perceived the injury had affected their sporting performance. If “Yes”, they were instructed to select all relevant responses from a drop-down list (developed in the focus groups) of ways their breast injury might have affected their performance (see Table 8). Players were also able to select “Yes, other”, with space to write a free response describing how the injury affected their sporting performance. Selecting any “Yes” responses was recorded as confirmation of a breast injury being perceived to negatively affect their performance.

Football code: Players recorded their current primary football code as either AFL, Rugby League, Rugby Union (XVs) or Rugby 7s.

Player position: Players specified the position they primarily played in football and classified their current position as a forward, midfield (AFL only) or back.

Competition level: Players reported the highest level of football competition they had ever played as “regional”, “state”, “national” or “international”. The responses “regional”
Breast injury in contact football

and “state” were grouped to form a “sub-elite” category, whereas responses “national” and “international” were grouped as “elite”.

**Staff perceptions:** On the staff survey, coaches, medical professionals and other staff associated with female contact football teams recorded the football code(s) they were affiliated with and their role with the team. Staff were asked if they perceived that soft tissue contact injuries to the breast (e.g. bruising) are a problem for female contact football players, “Yes” or “No”. Staff also estimated the percentage of female contact football players they thought had ever experienced breast injuries, with options ranging from 0% to 100% in increments of 5%. Lastly, staff were asked to specify whether they perceived contact breast injuries had the potential to negatively affect the sporting performance of female contact football players, “Yes” or “No”. Lastly, staff were asked whether they had ever treated or provided treatment advice for a contact breast injury sustained by one of their players, “Yes” or “No”.

5.2.4 **Statistical analyses**

**Descriptive statistics:** Basic frequency counts were used to calculate the overall percentage of players who reported experiencing a contact breast injury, each cause of a contact breast injury and the perception that a contact breast injury negatively affected their sporting performance, as well as the percentage of staff who perceived that contact breast injuries were problematic for female contact football players and who perceived that contact breast injuries could affect the performance of their players.

**Chi-squared Test of Homogeneity:** The Crosstabs procedure was used to generate contingency tables, which summarised the distribution of players who reported contact breast injuries and those who perceived these injuries to affect their performance across the different football codes, player positions and competition levels. Differences in the proportions among the groups within each of these categories was assessed using a Chi-
Squared Test of Homogeneity. When one of the expected cell counts was below 5 (contact breast injuries caused by the ground in AF), Fisher’s Exact Test was used. Post hoc analysis using the Z-Test of Two Proportions provided pairwise comparisons within each category (football code, player position, competition level). Differences in the proportions between groups were considered statistically significant at \( p < 0.05 \). Although multiple statistical tests were conducted, no adjustment to the alpha level was deemed necessary given the exploratory nature of the study and the low cost associated with incurring an error (Sinclair et al. 2013). All statistical calculations were conducted using the Statistical Package for the Social Sciences (Version 23; SPSS Inc., Chicago, USA).

5.3 Results

5.3.1 Player participants

Football code, player position and competition level of the 297 female contact football players who completed the survey are depicted in Figure 7. Participants ranged in age from 16–48 years (mean 23.7 ± 5.7 years). Their self-reported bra sizes ranged from 6A–20DD (Australian bra sizing; see Appendix A for international bra sizing).

Figure 7: The percentage of player participants (n = 297) representing each (A) football code, (B) player position a, and (C) competition level.

a Two participants recorded multiple primary playing positions and were excluded from this graph and player position analysis only; forwards and backs in AFL and Rugby codes were grouped for this graph only.
5.3.2 *Occurrence, causes and perceived performance effects of breast injuries*

Fifty-eight percent of participants (n = 172) reported experiencing a contact breast injury during football training or matches. Specifically, 49% of participants (n = 142) reported a breast injury caused by contact with another player, 29% (n = 83) reported a breast injury caused by contact with the ball and 16% (n = 46) reported a breast injury caused by contact with the ground. Of the 172 participants who experienced a contact breast injury, 48% (n = 82) perceived that the injury negatively affected their performance. The negative performance effects reported by participants are listed in Table 8.

**Table 8:** Number and percentage of total participants who perceived negative performance effects as a result of their contact breast injuries (n = 82). Participants were able to select multiple options.

<table>
<thead>
<tr>
<th>Perceived performance effect</th>
<th>n</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distracted by the pain of a breast injury</td>
<td>31</td>
<td>19</td>
</tr>
<tr>
<td>Less likely to dive or tackle because of a current breast injury</td>
<td>27</td>
<td>16</td>
</tr>
<tr>
<td>Unable to run comfortably because of a breast injury</td>
<td>23</td>
<td>14</td>
</tr>
<tr>
<td>Less confident because of a breast injury</td>
<td>22</td>
<td>13</td>
</tr>
<tr>
<td>Less likely to dive or tackle for fear of getting a breast injury</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>Performance affected by general pain from breast injury</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Restricted arm movement caused by breast injury</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

* Performance effects of breast injuries reported in the “other” category

5.3.3 *Breast injuries by football code, player position and competition level*

A greater percentage of Rugby Union (XVs) players reported sustaining breast injuries caused by contact with another player (63%) compared to AFL players. A significantly lower percentage of AFL players reported sustaining breast injuries due to ground contact (7%; see Figure 8) compared to players from the other codes. As depicted in Table 9, there was a significant association between AFL player position and the cause of breast injury, such that significantly fewer AFL backs reported breast injuries caused by contact with another player than either forwards or midfielders. No association was observed
between Rugby player positions and either the occurrence or causes of breast injury. Significantly more sub-elite participants perceived that contact breast injuries negatively affected their performance (54%) compared to elite participants (see Figure 9).

Figure 8: Percentage of participants from each football code who reported sustaining any contact breast injury, a contact breast injury caused by another player, the ball or the ground and negative performance effects as the result of their contact breast injury.

* indicates a significant ($p < 0.05$) between-group difference.
Table 9: Percentage of participants from each player position within AFL and within all Rugby codes (League, Union, 7s) who reported sustaining any contact breast injury, a contact breast injury caused by another player, the ball or the ground and negative performance effects as the result of their contact breast injury.

<table>
<thead>
<tr>
<th>Variable</th>
<th>AFL (n = 125)</th>
<th>All Rugby codes (n = 172)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forward (n = 30)</td>
<td>Midfield (n = 55)</td>
</tr>
<tr>
<td>Any contact breast injury</td>
<td>57</td>
<td>56</td>
</tr>
<tr>
<td>Another player</td>
<td>45</td>
<td>47</td>
</tr>
<tr>
<td>Ball</td>
<td>31</td>
<td>38</td>
</tr>
<tr>
<td>Ground (^b)</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Perceived performance effects</td>
<td>59</td>
<td>36</td>
</tr>
</tbody>
</table>

\(^a\) statistically significant \((p < 0.05)\) difference in proportion of injuries between forwards and backs and between midfielders and backs.

\(^b\) Proportion of contact breast injuries caused by the ground in AFL was assessed using Fisher’s Exact Test.

Figure 9: Percentage of participants from each competition level who reported sustaining any contact breast injury, a contact breast injury caused by another player, the ball or the ground and negative performance effects as the result of their contact breast injury.

* indicates a significant \((p < 0.05)\) between-group difference.
5.3.4 Awareness and perception of breast injuries by staff

Of the 242 respondents to the staff survey (see Tables 10 and 11 for staff roles), 52% (n = 126) perceived that breast injuries were problematic for female contact football players. Most staff estimated that contact breast injuries were experienced by fewer than 5% of female contact football players (see Figure 10). Seventy percent of the staff (n = 167) perceived that contact breast injuries could negatively affect the performance of their players. Only 13% of staff (n = 30) reported treating or providing treatment advice for a breast injury.

<table>
<thead>
<tr>
<th>Code affiliation</th>
<th>Staff (n = 242)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFL</td>
<td>124</td>
</tr>
<tr>
<td>Rugby League</td>
<td>71</td>
</tr>
<tr>
<td>Rugby Union (XVs)</td>
<td>34</td>
</tr>
<tr>
<td>Rugby 7s</td>
<td>27</td>
</tr>
</tbody>
</table>

Table 10: Number of staff who responded to the staff survey from each football code.

<table>
<thead>
<tr>
<th>Role</th>
<th>Staff (n = 240)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coach</td>
<td>138</td>
</tr>
<tr>
<td>Other athletic staff</td>
<td>57</td>
</tr>
<tr>
<td>Physiotherapist</td>
<td>17</td>
</tr>
<tr>
<td>Doctor</td>
<td>10</td>
</tr>
<tr>
<td>Other medical staff</td>
<td>18</td>
</tr>
</tbody>
</table>

Table 11: Number of staff who responded to the staff survey, classified by staff role.

*Staff respondents were able to specify affiliations with more than one football code

Two staff respondents did not specify their role

Figure 10: Frequency distribution of the occurrence of contact breast injuries estimated by the staff respondents (n = 242).
5.4 Discussion

5.4.1 Occurrence, causes and perceived performance effects of breast injuries

Consistent with the first hypothesis (H1), a greater percentage of participants in the current study (58%) reported experiencing a contact breast injury during football training or a match compared to a previous survey (44%), in which the participants from both contact sports (e.g. football codes) and combat sports (e.g. boxing, fencing) were combined into a single group for analysis (see Chapter 4, Section 4.3.3). The percentage of contact breast injuries reported in the current study is also greater than those previously reported by two diverse samples of athletes (29%, see Chapter 4, Section 4.3.3 and 48%, Smith et al. 2018). The findings of the current study therefore support the notion that a higher percentage of females involved in contact football sustain contact breast injuries relative to other athletes, including those involved in combat sports.

Understanding the causes of contact breast injuries in female contact football players is crucial to develop evidence-based prevention and management strategies (O’Brien et al. 2019). Although the most frequently reported cause of contact breast injuries was direct contact with another player, further research is needed to investigate the specific mechanisms of these player-to-player contact breast injuries, as per the second phase of the Team-sport Injury Prevention framework (O’Brien et al. 2019). For example, this player-to-player contact might have occurred during a tackle, in a ruck or during a scrum collapse. As strategies to reduce breast injuries are likely to differ depending on how an injury occurred, it is recommended that future research investigate the specific mechanisms associated with each cause of contact breast injury (i.e. contact with another player, the ball and the ground).

The high percentage of players who perceived that their contact breast injuries negatively affected their sporting performance relative to athletes from other sports is
Breast injury in contact football

concerning. Players reported that their breast injury negatively affected their sporting performance because they were distracted by the pain associated with the injury, the injury made them hesitant to dive or tackle or it was uncomfortable to run. Interestingly, players who had previously sustained a breast injury also reported that fear of sustaining another breast injury made them less likely to dive or tackle. This finding emphasises the need to provide all players with evidence-based strategies to prevent breast injuries so that players can enjoy their sport and focus on their performance without fear of incurring a breast injury. Female contact football players should also be involved in the development of any future program designed to prevent and manage breast injuries to ensure that the strategies are both effective for, and perceived to be effective by, the players who will use them.

5.4.2 Breast injuries by football code

Consistent with the second hypothesis (H2), a significantly higher proportion of Rugby Union (XVs) players reported breast injuries caused by direct contact with another player compared to the proportion of AFL players who reported similar breast injuries. These findings are also consistent with previous research, which revealed the highest frequency of tackling in Rugby Union (XVs) and the lowest in AFL (Gray and Jenkins 2010; Orchard and Seward 2009). Although tackling has been associated with the highest number of general sports injuries in Rugby Union, (Fuller et al. 2007a; Sports Medicine Australia 2017) it is also important to consider how and where players’ breasts might be injured by contact with other players beyond tackling. For instance, Rugby Union (XVs) players might be exposed to contact breast injuries caused by another player during scrums, rucks, mauls or when fending off another player. Although increased tackling frequency and these unique contact events might explain the higher occurrence of contact breast injuries within Rugby Union (XVs) compared to AFL, future research is
encouraged to explore specifically how and when players are injuring their breasts during contact with another player.

Similarly, a significantly higher percentage of Rugby League, Rugby Union (XVs) and Rugby 7s players all reported breast injuries caused by contact with the ground compared to AFL players. This is likely because AFL players do not engage in activities such as scrums like the other rugby codes, in rucks or mauls like Rugby Union and Rugby 7s or tackle with the same frequency as Rugby Union and Rugby League players (Gray and Jenkins 2010; Orchard and Seward 2009), thus decreasing the likelihood of ground contact. However, the long distance, high velocity kicks that are characteristic of AFL (Ball 2007; Ball 2008) might result in high impact forces to the breasts when players “mark” (catch) the ball or attempt to spoil/smother the ball within close proximity to the kicker. This possibly explains why the highest proportion of breast injuries caused by the ball were reported by AFL players.

Rugby League and Rugby Union players also reported a relatively high occurrence of breast injuries caused by the ball, although it is possible that these ball injuries may have been caused by landing on the ball during a tackle or in a scrum, or from being forcefully tackled while carrying the ball. The disparate occurrence of breast injuries within each of the football codes provides a basis upon which to develop sport-specific strategies to prevent and manage contact breast injuries. However, future research is also needed to determine specifically how and when female contact football players are injured during their sport (e.g. during a ruck, catching the ball, etc.) because the mechanisms of injury might differ between football codes due to unique match demands.

5.4.3 Breast injuries by player position

In contrast to the second hypothesis, the only significant difference in injury occurrence between player positions was that a smaller proportion of AFL backs reported injuries
caused by contact with another player compared to forwards or midfielders. This is somewhat consistent with previous research, which has reported that AFL midfielders engage in the greatest frequency of tackles and collisions during matches compared to other player positions (Clarke et al. 2018). However, the high proportion of breast injuries caused by contact with other players in AFL forwards and midfielders is not necessarily related only to tackles and collisions. In addition to their offensive role in scoring goals, AFL forwards maintain defensive pressure on opposing players when the ball has been lost and, as such, are vulnerable to frequent physical contact with other players while attempting to maintain or gain possession, or to spoil the ball. This frequent player-to-player contact in forwards and frequent tackling in midfielders is likely to result in a high proportion of contact breast injuries for both player positions when compared to backs.

The lack of significant effect of playing position on breast injuries in the rugby codes was surprising, considering previous research that has documented a greater tackling frequency among forwards compared to backs in both male Rugby Union (Cunniffe et al. 2009; Roberts et al. 2008) and Rugby League (Gabbett 2007; Gissane et al. 2001) players. However, tackling is just one possible way in which players in these football codes might be injured. Furthermore, the present study only queried whether participants had ever experienced a breast injury during their sport. It is possible that the frequency of contact breast injuries varies as a result of disparate tackling frequencies amongst different player positions, although this notion is yet to be investigated. Future research is therefore recommended to examine the number of contact breast injuries experienced by female contact football players, relative to the number of match hours they play, and how breast injury incidence is affected by player position. Research is also encouraged to explore the specific mechanisms of contact breast injuries within AFL and the Rugby codes, as these might vary substantially between player positions.
5.4.4 Breast injuries by competition level

Contrary to the second hypothesis, competition level did not significantly affect the occurrence or causes of contact breast injuries in this cohort of female contact football players. This finding is in contrast to previous studies of male Australian Football players (Gabbe et al. 2002; Seward et al. 1993), Rugby League players (Gabbett 2004) and Rugby Union (XVs) players (Garraway et al. 2000), which have revealed that injuries generally increase as playing level increases. It is speculated that technique and proficiency differences responsible for the disparate injury rates and tackling frequencies between elite and sub-elite male football players is not yet as apparent in females due to the recency of high-level women’s contact football in Australia. The greater percentage of sub-elite participants who perceived that their breast injuries negatively affected their football performance compared to their elite counterparts could also reflect the tendency of high-performance athletes to “play through pain” (Deroche et al. 2011; Malcom 2006; Nixon 1993; Roderick et al. 2000). However, the frequency of breast injury was not queried and therefore the incidence might vary between sub-elite and elite players as a result of skill level. Despite this limitation, contact breast injuries are occurring across all competition levels, with half of female contact football players perceiving these injuries to negatively affect their football performance. These findings again emphasise the need to develop evidence-based injury prevention and management strategies to minimise the negative effects of contact breast injuries on football performance, and potentially on sustained participation, for players of all levels.

5.4.5 Awareness and perception of breast injuries by staff

This is the first study to directly survey coaches, medical professionals and other staff associated with women’s contact football teams about their awareness and perception of contact breast injuries experienced by female players. Although fewer than half of the
staff who responded to the survey perceived that breast injuries were problematic for contact football players, 70% believed that breast injuries had the potential to negatively affect player performance. It therefore appears that coaches, medical professionals and staff associated with female contact football teams perceive that breast injuries are a potentially serious injury, but that they do not affect a large proportion of players. This notion was further supported by the perception of many staff that only 5% of players had experienced breast injuries, in direct contrast to the 58% of players in the current study who reported sustaining a contact breast injury during training or a match.

Only injury prevention strategies or safety procedures that are adopted by coaches and other sport staff will prevent injuries (Finch 2006; White et al. 2014). A coach’s involvement, however, is highly dependent upon his or her perceptions about the injury and the strategy (Finch 2006; White et al. 2014). Therefore, the incorrect perception by staff that breast injuries are not problematic and rarely occur in football has the potential to hinder implementation of future breast injury prevention strategies in women’s contact football. The lack of staff awareness about breast injuries might also contribute to the low number of players reporting these injuries (see Chapter 4, Section 4.3.2; Smith et al. 2018), because discussions about breast injuries have not been normalised within contact football. An important implication of this study for clinicians and sporting bodies is therefore to raise awareness about breast injuries and “normalise conversations” about these injuries amongst female players, their coaches and medical professionals. Future injury surveillance should also consider player-reported systems and a specific item for breast injuries should be added to future injury classification lists to ensure that breast injuries are recorded.
5.4.6 Limitations

As the results of the present study are based on surveys, it is necessary to acknowledge the inherent limitations associated with self-reported data, such as recall bias. Although every effort was made to recruit a representative sample of female contact football players for the player survey, it is also possible that women who had experienced breast injuries were more likely to participate. The use of an online survey and indirect recruitment methods also prevented the calculation of an accurate response rate for either the player or staff survey, and no data was collected on staff gender, although it is possible this may have influenced awareness of breast injuries. Despite these limitations, the present study was exploratory research which established that breast injuries are a problem for female contact football players and that staff are often unaware of their occurrence. These results should be used to inform future research into the specific incidence, frequency and mechanisms of breast injuries.

5.5 Conclusion

Over half of the female AFL, Rugby League, Rugby Union (XVs) and Rugby 7s players in this study reported sustaining contact injuries to their breasts, and many of these players perceived that breast injuries negatively affected their sporting performance. Causes of contact breast injuries varied with football code and player position, although further research is required to determine specific mechanisms of injury. Despite a high percentage of players reporting they had experienced a contact breast injury, coaches and medical professionals had limited awareness of these injuries and many staff perceived that contact breast injuries were not an issue for female contact football players. Athletes, coaches and medical professionals therefore need to be educated about the potential for, and the effects of, contact breast injuries in the football codes so that these injuries can be prevented and managed.
Chapter 6

Use and perception of breast protective equipment by female contact football players

This chapter is an amended version of the published manuscript: Brisbine BR, Steele JR, Phillips EJ and McGhee DE. Use and perception of breast protective equipment by female contact football players. Journal of Science and Medicine in Sport. 2020. doi:10.1016/j.jsams.2020.02.004

Abstract

Female contact football players sustain contact breast injuries that can negatively affect their sporting performance. This study aimed to investigate what female contact football players wear on their breasts when training and competing and whether they perceive any protection from these garments against contact breast injury. Two hundred and seven female AFL, Rugby League, Rugby Union (XVs) and Rugby 7s players completed a custom-designed survey about breast injuries and prevention strategies. Only 17% (n = 35) of participants reported using breast protective equipment, of which 66% (n = 23) perceived that it provided protection against contact breast injuries. Reasons reported for not using protective equipment included not knowing it existed (n = 79, 53%), it was too uncomfortable/hot (n = 50, 24%) and that it did not fit or was restrictive (n = 33, 22%). Although most participants (n = 97; 87%) reported wearing a sports bra, 52% (n = 58) wore an ill-fitted bra and only 31% (n = 63) perceived it provided any protection against contact breast injuries. Breast protective equipment is not commonly worn by female contact football players reportedly due to a lack of awareness of its existence, discomfort or poor fit. Although most female contact football players usually wore a sports bra, most players perceived these bras did not provide breast protection.
6.1 Introduction

Athletes who participate in full-contact sports, such as contact football, are at risk of sustaining acute contact-related injuries. Data presented in Chapter 5, for example, revealed that 58% of female Australian Rules Football (AFL), Rugby League, Rugby Union (XVs) and Rugby 7s players (n = 297) experienced contact injuries to their breasts (see Section 5.3.2). Nearly half of the players who reported sustaining a breast injury in this study also perceived that their breast injury negatively affected their sporting performance. It is therefore necessary to develop and implement evidence-based strategies to prevent and manage contact breast injuries for women who participate in the contact football codes in order to maximise performance and prevent any potential long-term issues that might occur as a consequence of a single or repeated breast injury. The 2019 Team-sport Injury Prevention (TIP) framework recommends that both the “current injury situation” and “current injury prevention situation” are evaluated before preventative strategies can be successfully implemented (O’Brien et al. 2019). Chapter 5 documented the “current situation” of contact breast injuries sustained by female contact football players, including the occurrence, causes, perceived performance effects of these injuries and the perceptions of contact breast injuries by athletic and medical staff. No published research, however, has investigated the injury prevention strategies used by female contact football players to prevent contact breast injuries.

Padding is often worn on various parts of the body as a strategy to prevent or minimise soft-tissue injuries, such as contusions or haematomas, by distributing contact forces across a larger surface area (Gerrard 1998; Marshall et al. 1999). All of the contact football codes, to varying degrees, permit the use of breast padding or other soft breast protective equipment during matches. World Rugby regulations explicitly permit the use of “breast padding” or “chest pads” for female Rugby Union (XVs) and Rugby 7s players,
even specifying design and material property guidelines for this breast padding (Regulation 12, Schedule 1, Section 7; World Rugby 2015). Although Rugby League regulations do not specifically list breast protective equipment, they stipulate that “protective clothing may be worn provided it contains nothing of a rigid or dangerous nature” (Section 4, Players’ Equipment 4(a); Australian Rugby League Commission 2019). In contrast, Australian Football League requires players to obtain approval from the General Manager to use any protective equipment other than thigh or shin pads, which would include the use of breast padding (Section 4.7(c); Australian Football League Commission 2019; see Table 16).

Despite World Rugby regulations permitting breast padding, researchers investigating general protective equipment used by female Rugby Union players (n = 234) found that none of the participants reported wearing any type of breast or chest padding (Comstock et al. 2005). Similarly, elite female athletes (n = 504) across a range of sports were surveyed in Chapter 4 and it was found that no participant from the contact football codes reported wearing any form of breast protection during training or matches (see Section 4.3.4). However, the exploratory study conducted in Chapter 4 only included 59 contact football players and did not investigate why breast or chest padding was not used or players’ perceptions of current protective equipment. Further research is therefore needed to investigate whether female contact football players use any form of breast protection, the reasons why or why not and the perceived protection of these garments against contact breast injuries so that the current injury prevention situation can be understood (O’Brien et al. 2019).

Independent of breast padding, most female athletes wear a sports bra to support their breasts while they train and compete (see Chapter 3, Section 3.3.1). Properly fitted and well-designed sports bras have been shown to reduce the amount of breast motion
Breast protective equipment

and, in turn, breast pain women experience when exercising (Lorentzen and Lawson 1987; McGhee et al. 2010b; Scurr et al. 2010). Twenty-nine percent of female athletes in a recent study (see Chapter 4, Section 4.3.4) even reported that they wore a sports bra as a breast injury prevention strategy. However, it is unknown whether bras are perceived to protect against breast injuries or are considered breast protective equipment by female contact football players. Sports bras differ in design (e.g. encapsulation bras support each breast in a separate cup, whereas compression bras compress the breasts as a single unit against the chest wall), the amount of breast coverage they provide and the amount of padding in the bra (Coltman 2017; Zhou et al. 2013). It is therefore possible that different sport bra designs may be perceived to protect the breasts against contact injuries by either holding the breasts closer to the chest wall (decreasing their protrusion from the chest wall) or by providing some form of padding over the breasts. No published research, however, has documented the breast support worn by female contact football players or the players’ perceptions as to whether sports bras can protect their breasts against contact injuries.

Given the high percentage of female contact football players who have reported experiencing breast injuries (see Chapter 5, Section 5.3.2), it is necessary to investigate the strategies players use or do not use to prevent contact breast injuries, the reasons behind these decisions and their perceptions of these prevention strategies, including any potential negative effects. Such information is crucial to inform future research on breast injuries and the development of evidence-based breast injury prevention strategies (O’Brien et al. 2019). Therefore, this study aimed to investigate: (i) whether female contact football players used any breast protective equipment, such as breast or chest padding, and their perceptions about whether this equipment protected their breasts against contact injury and (ii) the fit and features of the players’ breast support and their
perceptions about the protection provided by these garments against contact breast injuries. Based on the current literature, it was hypothesised that:

H1: a limited number of female contact football players would wear breast padding, but that it would be perceived to protect their breasts against contact injury.

H2: most female contact football players would wear a bra during training and matches and it would also be perceived to protect their breasts against contact injury.

6.2 Design and methods

6.2.1 Survey development and implementation

An anonymous 17-question survey was designed to gather data on the use of breast or chest padding and bras by female AFL, Rugby League, Rugby Union (XVs) and Rugby 7s players, as well as whether the players perceived these garments to be effective in protecting their breasts against contact breast injury (a full copy of the survey is provided in Appendix C). The survey design and recruitment procedures were the same as those listed for the player survey in Chapter 5, Section 5.2.1. In brief, the link to an online version of the survey was distributed via email, social media posts and fliers to football clubs, sporting organisations and coaches around Australia, who could then choose to share the link to the survey with their players. Survey participants were also consistent with those reported in Section 5.3.1; however, data from participants who did not answer all questions relevant to the current study were excluded from the analysis (see Section 6.3.1 below).
6.2.2 Breast support assessment

Where geographically feasible, players who completed the survey were also invited to participate in an additional 15-minute breast support assessment session. This assessment was conducted at the Biomechanics Research Laboratory, University of Wollongong, or within a secure testing space at the facilities where the participants trained. The study approval procedures were the same as those reported in Chapter 5, Section 5.2.2 and this study also received official endorsement from the Chief Medical Officers of the Australian Football League and Rugby Australia (Rugby Union), the National Rugby League Research Committee and World Rugby (Rugby Union and Rugby 7s).

6.2.3 Analytical variables

Use of breast protective equipment: Survey participants were asked whether they used “breast padding”, “shoulder pads with chest pads”, “other protective equipment” or “no protective equipment” to prevent breast injuries while playing contact football. Those participants who did not use protective equipment were asked to indicate all relevant reasons for not using protective equipment from a drop-down list, which was developed through a focus group (described in Section 5.2.1), together with an open-ended response so the participants could provide reasons not included in the list (see Table 13).

Perceived effectiveness of breast protective equipment: Survey participants who reported using breast padding or shoulder pads with chest pads were asked whether they perceived it to be effective in preventing contact breast injuries (“yes” or “no”). Participants were also asked to rate, on a 5-point Likert scale from “excellent” (1) to “terrible” (5), how much breast protection they perceived the bra they wore during training and matches provided against contact breast injuries. Responses “excellent” (1) and “good” (2) were considered a positive perception that their bra provided breast protection.
Use of breast support: Participants were asked to wear to the testing session whatever breast support they typically wore during training and matches. The type of breast support worn by each participant was recorded as: (i) encapsulation sports bra (moulded cups, with or without underwire), (ii) compression sports bra (crop top without moulded cups), (iii) hybrid sports bra (encapsulation and compression), (iv) everyday bra (cups with underwire), (v) bralette (non-moulded cups without underwire) or (vi) no breast support (see Figure 1).

Bra fit: The fit of each participant’s bra was assessed by the primary investigator [BRB] using a modified version of the professional bra fitting criteria developed by McGhee and Steele (2010b; see Table 12). Prior to data collection, the primary researcher received extensive one-on-one training in bra fit and was deemed to be highly proficient and consistent in performing the assessment by the expert who developed the professional bra fit criteria. The modified fit checklist considered four bra components in determining overall bra fit: the back band, the shoulder straps, the bra cups and the underwire (if applicable). If all four bra components fitted correctly without requiring any adjustment, the overall bra fit was considered a “pass”. If one or more components did not fit the participant correctly, the overall bra fit was considered a “fail”.

Bra features: Each participant’s bra was also recorded as providing either “complete” or “incomplete” coverage based on how much of the breast was covered by the bra cups (or material of the bra that overlayed the breast). Finally, thickness of the padding at the superior and inferior aspect of each participant’s bra cup was measured using callipers (150 mm; Kinchrome Professional Quality Tools, Scoresby, Australia) and recorded as no padding (<1 mm), low padding (1–4 mm), medium padding (4.01–10 mm) or high padding (>10 mm). If a participant wore more than one bra simultaneously, breast coverage and padding thickness of the bra combination was assessed.
Breast protective equipment

(i) Compression sports bra
Crop top without separate cups

(ii) Hybrid sports bra
Compression and encapsulation

(iii) Encapsulation sports bra
Separate cups, with or without underwire

(iv) Everyday bra
Separate cups with underwire

(v) Bralette
Without separate cups, without underwire

Figure 11: Types of breast support.

Table 12: The bra fit criteria (modified from McGhee and Steele 2010b) used in this study to assess the fit of each athlete’s bra(s).

<table>
<thead>
<tr>
<th>Component</th>
<th>Criteria a</th>
</tr>
</thead>
</table>
| Back band | □ Too tight: flesh bulging over the top of band; subjective discomfort “feels too tight”  
□ Too loose: band lifts up with movement of arms above the head; posterior band not level with inframammary fold |
| Straps    | □ Too tight: straps digging in; subjective discomfort; carrying too much of the weight of the breasts  
□ Too loose: straps sliding off shoulder |
| Cups      | □ Too small: breast tissue bulging out of cups, below cups or at the sides  
□ Too big: wrinkles in cup fabric or gaps between breast and cup |
| Underwire | □ Incorrect shape: underwire sitting on breast tissue laterally (under armpit) or anterior midline; subjective discomfort  
(N/A if athlete is wearing a bra without underwire) |
| Overall fit | □ Pass: fit in all categories  
□ Fail: any ticks |
6.2.4 Statistical analyses

Descriptive statistics: The number of survey-respondents who reported wearing breast protection, who reported various reasons for not wearing breast protection, who perceived that their chosen breast or chest padding protected them from contact breast injuries and who perceived their bras protected their breasts from contact injuries was counted. The percentage of the total number of survey respondents (n = 207) from each contact football code who reported using breast padding, shoulder pads combined with chest pads or no padding during training and matches was calculated and compared using a contingency table. From the participants involved in the direct breast support assessment (n = 112), the number of participants who wore each of the five bra types listed above, the number who failed the bra fit assessment and the frequency of the different bra cup features worn by the participants were also counted.

Chi-squared Test of Independence: The SPSS Crosstabs procedure was then used to generate a contingency table to summarise the distribution of participants who passed or failed the bra fit assessment according to what type of bra(s) they wore. Differences in the proportion of participants who passed the bra fit assessment between groups (i.e. based on the type of bra they wore) were assessed using a Chi-squared Test of Independence ($p < 0.05$). Two cells had expected counts less than 5, violating the assumptions of this test; therefore, the exact $p$-value was reported. All statistical calculations were conducted using the Statistical Package for the Social Sciences (Version 23; SPSS Inc., Chicago, USA).

6.3 Results

6.3.1 Participant characteristics

Characteristics of the participants who completed the survey (n = 207) and those who also participated in the breast support assessment (n = 112) are included in Figure 12.
6.3.2 Survey

Of the 207 survey respondents, breast padding or shoulder pads with chest pads were worn by 17% (n = 35) of the participants during training and matches, although this percentage varied among the contact football codes (see Figure 13). Of these 35 participants who wore breast protection, three reported using specific breast padding, and two of these three participants perceived this padding to be effective in preventing contact breast injuries. The other 32 participants (16%) reported using shoulder pads combined with chest pads, which were perceived to be effective in preventing contact breast injuries by 21 of these 32 participants. The reasons participants reported for not using breast protective equipment are presented in Table 13. Thirty-one percent of the survey respondents (n = 63) perceived that their bra(s) provided either “excellent” or “good” protection against breast injury.
Female contact football players invited to participate in a survey and/or breast support assessment

Inclusion criteria:
- 18+ years of age
- > 1 season of football

305 players submitted the online survey

Excluded:  
- Incomplete responses (n = 98)

207 players completed the survey  
- 82 AFL, 47 Rugby League, 43 Rugby Union XVs, 35 Rugby 7s  
- 110 regional, 23 state, 62 national, 12 international competition level players  
- Mean age 23.8 ± 5.9 years  
- Self-reported Australian bra sizes 6A to 20DD

117 players who completed the survey also participated in the breast support assessment session

Excluded:  
- Did not wear their usual training or match bra (n = 5)

112 players completed the breast support assessment  
- 60 AFL, 20 Rugby League, 17 Rugby Union XVs, 15 Rugby 7s  
- 90 regional, 5 state, 11 national, 6 international competition level players  
- Mean age 25.2 ± 6.0 years  
- Breast volume $406.8 \pm 245.5$ mL ($85.3 - 1616.1$ mL)

**Figure 12:** Flow of participants through the present study.
Breast protective equipment

Figure 13: Participants (n = 207) from each contact football code who reported using breast padding, shoulder pads with chest pads or no padding during training and matches.

Table 13: Reasons given by participants (n = 150) for not using breast or chest protective equipment during training and matches.

<table>
<thead>
<tr>
<th>Reason for not using breast protection</th>
<th>Number (%) of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Didn’t know it existed</td>
<td>79 (53)</td>
</tr>
<tr>
<td>Uncomfortable</td>
<td>28 (19)</td>
</tr>
<tr>
<td>Too hot/not breathable</td>
<td>22 (15)</td>
</tr>
<tr>
<td>Not necessary</td>
<td>22 a</td>
</tr>
<tr>
<td>Restrictive to my upper body/arms</td>
<td>21 (14)</td>
</tr>
<tr>
<td>Not effective in preventing breast injury</td>
<td>12 (8)</td>
</tr>
<tr>
<td>Doesn’t fit my breast/torso shape</td>
<td>12 (8)</td>
</tr>
<tr>
<td>Not permitted to use in my sport</td>
<td>7 (5)</td>
</tr>
<tr>
<td>Don’t want to wear men’s padding</td>
<td>3 (2)</td>
</tr>
<tr>
<td>Would feel “silly” wearing it</td>
<td>2 a</td>
</tr>
</tbody>
</table>

*a Free responses included in the analysis

6.3.3 Breast support assessment

Of the 112 female contact football players who participated in the breast support assessment, the most commonly-worn bra type was a compression sports bra (62%; n =
69), followed by an encapsulation sports bra (21%; n = 23), an everyday bra (13%; n = 15) and a hybrid sports bra (4%; n = 5). No participant wore a bralette or went without some form of breast support during training or matches. Of the 69 participants who wore compression sports bras, seven wore another bra underneath: i.e. one participant wore two compression sports bras, three participants wore a compression sports bra with an everyday bra and three participants wore a compression sports bra with an encapsulation sports bra. There was a statistically significant association between bra type and bra fit ($\chi^2(3) = 16.063, p = 0.001$), whereby significantly more participants who wore compression sports bras (62%) passed the bra fit assessment compared to participants who wore encapsulation sports bras (35%), hybrid sports bras (20%) or everyday bras (13%). The association between bra type and bra fit was moderate (Cramer’s $V = 0.379$) (Cohen 1988).

Overall, 52% of participants (n = 58) did not pass the bra fit assessment based on one or more ill-fitting components. The greatest number of participants failed the bra fit assessment on the basis of the bra cups being too small (n = 20; 18%), followed by the back band being too loose (n = 19; 17%), the bra cups being too large (n = 18; 16%), the bra straps being too loose (n = 14; 13%), the back band being too tight (n = 11; 10%) or the bra straps being too tight (n = 5; 5%). Of the 39 participants who wore an underwire bra (i.e. an encapsulation sports bra with underwire or an everyday bra), 23% (n = 9) failed the bra fit assessment on the basis of incorrectly shaped underwire that did not conform to their breasts. Fifty-five percent of participants (n = 58) wore breast support with incomplete breast coverage. Bra cup padding thickness at the inferior and superior cups is presented in Figure 14.
Discussion

This was the first study to investigate breast protective equipment, including breast padding and breast support, worn by female contact football players, reasons why some players choose not to use breast protective equipment and the perceived protection provided by these garments against contact breast injury. The majority of participants reported not wearing any type of breast or chest padding during training and matches; of the small percentage that did, approximately one-third perceived that it was effective in preventing contact breast injuries. Most participants wore sports bras and some perceived that their sports bras provided protection against contact breast injuries. This was despite a high number of players failing the bra fit assessment, wearing bras that did not completely cover their breasts or that had only low levels of padding. The implications of these findings are discussed below.

6.4.1 Breast padding as breast protective equipment

The very small percentage of participants (n = 35; 17%) who reported using breast protective equipment was consistent with two previous studies, in which female Rugby
Breast protective equipment

Union players (Comstock et al. 2005) or players from all four contact football codes (see Chapter 4). Specific regulations have been drafted by World Rugby to allow female players to wear appropriate breast padding (World Rugby 2015), and yet extremely few Rugby Union or Rugby 7s player reported using breast padding. However, the finding that most of the participants who used protective equipment (23 of the 35 participants) perceived it to be effective in protecting their breasts suggests that protective equipment might be a potential strategy to decrease the risk of breast injury.

The most common reason reported (by approximately 50% of the participants) for not wearing protective equipment was not knowing it existed. It is imperative that female contact football players are aware of all potential breast protection options so that they can make informed injury prevention choices. Education for players participating in the female football codes is therefore recommended to improve their awareness of available breast protective equipment. Many participants also reported that they did not wear breast protective equipment because they found it to be uncomfortable, too hot, restrictive to their arms or ill-fitting for their body shape, suggesting that existing breast or chest padding is not properly designed or sized to fit female contact football players and could even negatively affect a player’s performance. If the physical comfort and/or sporting performance of players is compromised by using breast or chest padding, the players are unlikely to use these garments and coaches are unlikely to recommend them, irrespective of whether breast protective equipment is perceived to be effective in preventing contact breast injuries. Player perceptions of breast protective equipment and their specific torso and breast anthropometry should also be incorporated into any further research to inform and improve breast protective equipment design, fit and use to reduce breast injuries, as per the TIP framework (O’Brien et al. 2019).
6.4.2 Sports bras as breast protective equipment

Although most of the participants who attended the breast support assessment session wore a bra(s) that provided incomplete breast coverage with minimal padding in the cups, one-third of the participants who completed the survey rated their bra as providing “excellent” or “good” protection of their breasts against contact injury. This suggests that breast coverage or bra cup padding might not be features that protect the breasts against injury. Participants, however, were not directly asked about bra features that contributed to their perception of breast protection or any details of exactly how and to what extent their bras provided protection. Further investigation of the level of protection provided by sports bras, as well as breast protective equipment, is therefore recommended.

Previous research has also revealed that athletes with larger breasts are more likely to sustain contact breast injuries during sport, most likely because larger breasts protrude further from the trunk and have a greater surface area for potential contact (see Chapter 4, Section 4.3.3). It is therefore possible that highly compressive sports bras, which hold the breasts firmly against the torso, might be perceived as protective against contact breast injuries by decreasing anterior protrusion of the breasts. Further research is required to specifically investigate which bra characteristics contribute to protecting breasts from contact injuries, such as compression, so that players can be provided with evidence-based guidelines for selecting appropriate sports bras to wear during football training and matches.

Interestingly, the proportion of participants that failed the bra fit assessment in this study (52%) was lower than has been reported in previous research based on the general female population (85% to 100%; Coltman et al. 2018b; Greenbaum et al. 2003; McGhee and Steele 2010b). This finding was attributed to female contact football players predominantly wearing compression sports bras (i.e. crop tops), which do not have
Breast protective equipment

separate cups or underwire and therefore might be easier to correctly fit. Indeed, a higher proportion of participants who wore compression sports bras passed the bra fit assessment compared to participants wearing any other type or combination of bras. Nevertheless, more than half of the study participants were found to be wearing an ill-fitting bra. As a bra must fit correctly in order to properly support the breasts (Page and Steele 1999), it is also possible that proper bra fit might contribute to better protection against contact breast injuries. Therefore, it is recommended that female contact football players be educated about the importance of, and strategies to achieve, correct bra fit. It might also be necessary to investigate other strategies for improving sports bra fit and design for female contact football players to ensure that current breast support options are catering for these women.

6.5 Conclusion

Breast protective equipment is not commonly worn by female contact football players reportedly due to a lack of awareness of its existence, discomfort and poor fit. Of the small number of players who wore breast protection, however, most perceived it to be protective against contact breast injury. Although sports bras were worn by most players during training and matches, more than half of these players wore bras that did not fit correctly, and less than a third perceived that their bras protected their breasts from injury. Further research is required to investigate potential strategies to protect the breasts from contact injury in female contact football players. This research should investigate the design of protective equipment relative to the shape and dimensions of the breasts and torso of female contact football players, as well as its comfort and fit. Strategies to improve the bra fit of sports bras worn by female contact football players is also required, as well as examining the potential of sports bras to provide any protection against contact breast injury.
Part IV

Breast & torso characteristics of female contact football players
Chapter 7

Breast and torso characteristics of female contact football players: Implications for the design of sports bras and breast protective equipment

This chapter is an amended version of the published manuscript: Brisbine BR, Steele JR, Phillips EJ and McGhee DE. Breast and torso characteristics of female contact football players: Implications for the design of sports bras and breast protective equipment. *Ergonomics*. 2020. doi:10.1080/00140139.2020.1757161

Abstract

This study aimed to provide normative data characterising the breast size, breast position and torso size of female contact football players. One hundred and seventeen AFL, Rugby League, Rugby Union and Rugby 7s players attended a single testing session where a three-dimensional scan was taken of their naked breasts and torso. Dimensions deemed relevant to the design of sports bras and breast protective equipment were then calculated from the scans. Several breast and torso characteristics of female contact football athletes differed to measurements reported for females in the general population and amongst the contact football codes. Designers and manufacturers of sports bras and breast protective equipment should consider the specific breast and torso dimensions of female contact football players to maximise the fit, comfort and efficacy of these garments.
7.1 Introduction

The number of females participating in contact football codes, such as Australian Rules Football (AFL), Rugby League and Rugby Union, is rapidly increasing around the world (Navaratnam 2017; Rugby Australia 2018). In fact, more than a quarter of Rugby Union and 7s players internationally are girls and women (World Rugby 2018). To ensure the health and well-being of these players, it is necessary to address any unique injuries experienced by females when participating in the contact football codes. Based on the survey conducted in Chapter 5, 58% of female AFL, Rugby League, Rugby Union (XVs) and Rugby 7s players reported sustaining contact injuries to their breasts during training or matches. In addition to resulting in pain and discomfort, many players perceived that these breast injuries negatively affected their sporting performance (see Chapter 5, Section 5.3.2).

Despite sports medicine professionals recommending that breast protective equipment should be used to prevent breast injuries (Bayne 1968; Gehlsen and Stoner 1987; Haycock et al. 1978; Haycock 1978; Lawson 1991), very few players reported using any equipment to protect their breasts (see Chapter 6). Some of the main reasons that players reported for not using breast protective equipment were related to discomfort or poor fit of the garment (see Chapter 6, Section 6.3.2). In fact, due to the limited commercial availability of female-specific protective equipment, female contact football players are likely to be wearing chest pads designed for male players or no padding at all. However, given the differences in torso anatomy and chest dimensions between men and women (Fink et al. 2003; Furnell et al. 2014), it is unlikely that protective garments designed for a male chest will adequately accommodate female breasts. Improving the design of protective garments, such as breast and chest padding, to better accommodate
the shape of female breasts and torsos is therefore also likely to improve the fit and comfort of these garments for female contact football players.

In addition to breast and chest padding, some female contact football players perceive that their sports bra protects their breasts against injury during training and matches (see Chapter 6, Section 6.3.2). However, in a direct assessment of the bras worn by 112 female contact football players, more than half of the participants were found to be wearing an ill-fitting bra (52%) or a bra that provided incomplete coverage of their breast tissue (55%; see Chapter 6, Section 6.3.3). This high level of poor bra fit is not unique to female contact football players. That is, numerous studies have reported a similar level of poor bra fit in the general population (Coltman et al. 2018b; Greenbaum et al. 2003; McGhee and Steele 2010b) and emphasised the need to educate women about the importance of selecting a correctly-fitted sports bra (McGhee et al. 2010a). However, the physical characteristics of female athletes, such as height, mass, body mass index (BMI) and self-reported bra size, differ to those of the general female population (see Chapter 2, Section 2.3.1), upon whose dimensions sports bras have traditionally been designed. It is therefore possible that female contact football players are unable to achieve correct bra fit, irrespective of education about bra fit, due to their range of breast and torso characteristics relative to the variation in current designs and sizing of commercially available sports bras.

For sports bras and breast protective equipment, including breast or chest padding, to fit correctly and to function for the purpose it is designed for, the equipment must match the breast and torso characteristics of the wearer. Normative data of the breast and torso characteristics of female contact football players, however, are yet to be published. It is therefore unlikely that current sports bras or breast protective equipment have been designed to cater for the potentially unique dimensions of these athletes. Match formats
and physical demands vary between contact football codes (Coutts et al. 2010; Cummins et al. 2013; Cunniffe et al. 2009; Gray and Jenkins 2010; Orchard and Seward 2009; Waldron et al. 2011; Wisbey et al. 2010), which might contribute to differing physical characteristics of players. For example, the height (Clarke et al. 2014; Clarke et al. 2018; Jones et al. 2016) and body composition (Clarke et al. 2014; Clarke et al. 2017; Suarez-Arrones et al. 2014) of female football players appear to vary between codes. Considering that torso dimensions are likely to be influenced by height and that 50% of the variation in breast volume can be explained by a woman’s BMI (Brown et al. 2012; Coltman et al. 2017b), it is possible that AFL, Rugby League, Rugby Union and Rugby 7s players might have differing breast and torso characteristics, although this notion is yet to be specifically investigated. Normative data on the breasts and torsos of female contact football players is therefore needed to inform the design of breast protective equipment for these women, particularly if protective equipment designs directly incorporate breast support as well as protection. Improving the fit of sports bras and breast protective equipment is likely to enhance comfort when players wear these garments and, in turn, promote the use of breast protective equipment by contact football players.

The aim of this study was to characterise the size and shape of the breasts and torsos of women who participate in AFL, Rugby League, Rugby Union (XVs) and Rugby 7s to: (i) provide normative data on the breast and torso characteristics of female contact football players to inform the design of sports bras and breast protective equipment for these athletes, and (ii) identify any differences in the breast and torso characteristics among the different contact football codes. Based on the current literature, it was hypothesised that:

H1: female contact football players would display a wide range of breast and torso characteristics and
H2: these characteristics would differ among the contact football codes.

7.2 Design and methods

7.2.1 Experimental overview

Female AFL, Rugby League, Rugby Union (XVs) and Rugby 7s players aged 18 years and over and with at least one season of football experience were invited to participate in this study. Participants were recruited using email and fliers that were distributed to contact football coaches, team managers and development officers throughout Australia, who could then choose to share the study information with their players. The participants attended a single 15-minute testing session in the Biomechanics Research Laboratory at the University of Wollongong or in a secure room at their own training facility (e.g. the women’s locker room). During the testing session, the primary researcher [BRB], who is an accredited Level 1 Anthropometrist (International Society for the Advancement of Kinanthropometry) measured each participant’s height, mass, body fat percentage (using Tanita SC240MA Scales with in-built bioelectrical impedance analysis) and under-bust chest circumference (UBCC; described in Table 14). Each participant’s naked breasts and torso were then scanned with a hand-held three-dimensional scanner (the methods are described in Section 7.2.2 below) to create a computer-generated model for further analysis. All physical testing was approved by the University of Wollongong Human Research Ethics Committee (HREC 2017/009) and the Australian Institute of Sport Ethics Committee (20170610). The study also received endorsement from the Chief Medical Officers of the Australian Football League and Rugby Australia (Rugby Union), the National Rugby League Research Committee and World Rugby (Rugby Union and Rugby 7s).
7.2.2 Scanning the breasts and torso

Prior to scanning, adhesive dots (approximately 10 mm) were placed on each participant’s sternal notch and around the outer boundary of her breast tissue, which was identified by gently palpating the perimeters of her right and left breast (Coltman et al. 2017a; Coltman et al. 2017b; McGhee et al. 2018). The participant was then instructed to stand as still as possible on a custom-made turntable and look forward with her shoulders in slight abduction and extension, hands holding the turntable handles for stability (see Figure 15A). This “standard scan” position was chosen as it provided the most complete visualisation of the breasts for a majority of participants and most closely replicated the anatomical position of the breasts and torso (Coltman et al. 2017a; Lee et al. 2004; McGhee et al. 2018; Moyer et al. 2008; Veitch et al. 2012). Where a substantial portion of the inferior aspect of the breast could not be seen by the scanner due to breast ptosis (n = 4; Coltman et al. 2017a), an additional scan was taken with the participant placing her hands on her head (the “secondary scan” position; see Figure 15B). This secondary scan was used to calculate breast volume and surface area only for these four participants.

While maintaining the standardised stance, the breasts and torso of each participant were scanned using a hand-held three-dimensional scanner (Artec™ Eva 3D Scanner, Artec Group, San Jose, USA; 0.1 mm accuracy). To ensure consistency, the same experienced investigator identified all landmarks, attached all adhesive markers and performed the scanning.
Breast characteristics

Figure 15: Participants were scanned while holding the handles of a turntable that was slowly rotated (standard scan position, (A)). Participants whose level of breast ptosis prevented complete visualisation of their inferior breast were scanned while they held their hands on their head (secondary scan position, (B)).

7.2.3 Analytical variables

Six breast size measurements, four breast position measurements and two torso size measurements (see Table 14) were calculated from the scanned images using Geomagic Studio® software (Version 12; 3DSystems, South Carolina, USA). Linear anthropometric measurements, as well as three-dimensional measurements of breast volume and surface area, have previously been found to be accurate and valid when derived from three-dimensional scans (Han et al. 2010; Losken et al. 2005; Paquette et al. 2000; Qi et al. 2011; Yip et al. 2012). The UBCC of participants was measured manually using a measuring tape because circumferential measurements derived from three-dimensional scans have been found to be less accurate (Daanen and Hong 2008; Daanen and Ter Haar 2013; McGhee et al. 2018; Petrova and Ashdown 2008). All calculations were completed by the primary researcher, who had high reliability in deriving these measurements (all ICC >0.99; p <0.001). These measurements were selected because they were deemed
Breast characteristics

relevant to the design of sports bras and breast protective equipment based on previously published literature pertaining to breast characteristics (Coltman et al. 2017b; Coltman et al. 2018a; Lee et al. 2004; Liu and Thomson 2011; Moyer et al. 2008; Smith et al. 1986; Steele et al. 2017; Thomson et al. 2009; Veitch et al. 2012; Westreich 1997) or to bra design (Coltman et al. 2015; Coltman et al. 2017a; McGhee and Steele 2011; Zhou et al. 2013). Measurements were also based on the breast padding design guidelines published by World Rugby, the international governing body of Rugby Union (XVs) and Rugby 7s (World Rugby 2015). Details of how each measurement was obtained or calculated is provided in Table 14. Measurements calculated using the Geomagic® software are visually depicted in Figure 16.
Table 14: A description of how the breast size, breast position and torso size of each participant was directly measured or calculated, with the corresponding figures noted. Unless otherwise stated, all measurements were taken on each participant’s right and left breast and the mean value was recorded (Table 14 continued on next page).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description of how the variable was measured or calculated.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast volume (mL)</td>
<td>From each participant’s scan (Figure 15), a three-dimensional, isolated model of each breast was created by outlining the breast (Figure 16A), removing the breast from the torso (Figure 16B) and attaching it to the corresponding anterior chest wall to form a posterior breast wall (whose curvature approximated the superficial surface of the pectoralis major muscle; Figure 16C–D). These steps were performed to create a closed three-dimensional breast model (Figure 16E–F), from which breast volume (mL) was calculated.</td>
</tr>
<tr>
<td>Breast symmetry (%)</td>
<td>Using the closed three-dimensional breast model (Figure 16E–F), the difference between each participant’s right and left breast volume (as an absolute value) was divided by total breast volume to obtain a ratio of breast symmetry (%).</td>
</tr>
<tr>
<td>Breast surface area (cm²)</td>
<td>Using the closed three-dimensional breast model (Figure 16E–F), the surface area (cm²) of each participant’s right and left breast was calculated.</td>
</tr>
<tr>
<td>Surface area to volume (%)</td>
<td>The surface area (cm²) of each participant’s breasts was divided by the participant’s breast volume (mL) and expressed as a percentage (%).</td>
</tr>
<tr>
<td>Breast length (mm)</td>
<td>The vertical distance (mm) between the inferior and superior borders of each participant’s right and left breast was measured (Figure 16G).</td>
</tr>
<tr>
<td>Breast width (mm)</td>
<td>The horizontal distance (mm) between the medial and lateral borders of each participant’s right and left breast (along the curvature of the anterior chest wall; Figure 16H) was measured at the widest point.</td>
</tr>
</tbody>
</table>
Table 14: (Continued from last page) A description of how the breast size, breast position and torso size of each participant was directly measured or calculated, with the corresponding figures noted. Unless otherwise stated, all measurements were taken on each participant’s right and left breast and the mean value was recorded.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description of how the variable was measured or calculated.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sternal notch to nipple distance (mm)</td>
<td>The distance (mm) from the sternal notch (where a marker had been placed before scanning) to the nipple of each participant’s right and left breast was measured (Figure 16I).</td>
</tr>
<tr>
<td>Sternal notch to superior breast distance (mm)</td>
<td>The perpendicular distance (mm) from the sternal notch to a horizontal line drawn across the torso at the level of the superior border of each participant’s right and left breast (Figure 16J) was measured.</td>
</tr>
<tr>
<td>Breast bridge (mm)</td>
<td>The distance (mm) between the medial borders of each participant’s right and left breast was measured at the narrowest point (Figure 16K).</td>
</tr>
<tr>
<td>Lateral breast position (mm)</td>
<td>The distance (mm) from the most lateral border of each participant’s right and left breast to the anterior axillary line (a line in the coronal plane that begins at the anterior axillary fold, or the junction of the proximal arm and trunk) was measured (Figure 16L). Where the lateral border of the breast extended beyond the anterior axillary line, a negative value was reported.</td>
</tr>
<tr>
<td>Under-bust chest circumference (cm)</td>
<td>The circumference of each participant’s torso was measured in triplicate by placing a non-flexible measuring tape around her torso directly inferior to her breasts.</td>
</tr>
<tr>
<td>Chest width (mm)</td>
<td>The distance (mm) between each participant’s right and left anterior axillary fold (the anterior crease formed by the proximal arm and trunk on each side; Figure 16M) was measured along the natural surface curvature of the participant’s trunk.</td>
</tr>
<tr>
<td>Sternal notch to inferior breast (mm)</td>
<td>The perpendicular distance (mm) from the sternal notch to a horizontal line drawn across the torso at the level of the superior border of each participant’s right and left breast (Figure 16N) was measured.</td>
</tr>
</tbody>
</table>

Breast characteristics
Figure 16: Screenshots of an example of the steps taken to calculate the breast and torso measurements using Geomagic® software. Images (A)–(F) show how a three-dimensional model of the breast was created from the three-dimensional scan of each participant: (A) borders of the breasts were defined, (B) the breasts were removed from the trunk, (C) a posterior breast wall was created from the anterior chest wall, (D) the posterior breast wall shown from the side and the closed three-dimensional breast model shown from (E) the side and (F) the front. Images (G)–(N) show the distances calculated: (G) between the superior and inferior borders of the breast, (H) between the lateral and medial borders of the breast, (I) from the sternal notch to nipple, (J) from the sternal notch to the superior border of the breast, (K) between the medial borders of the breast at the narrowest point, (L) from the lateral border of the breast to the anterior axillary line, (M) between the right and left anterior axillary fold and (N) from the sternal notch to the inferior border of the breast.
7.2.4 Statistical analyses

Descriptive statistics were calculated for all measurements (mean, standard deviation, median and interquartile range) and boxplots were produced to visually depict the spread and shape of the data for the 13 variables. Tukey’s boxplot method was then used to detect whether there were any data points more than 1.5-times the interquartile range below the first quartile or above the third quartile (Schwertman et al. 2004; Tukey 1977). This test revealed that 11 of the 13 breast and torso measurements failed to meet the assumptions of parametric statistics due to outliers. Therefore, a series of independent samples Kruskal-Wallis H tests, chosen for its resilience to outliers, was conducted for these variables to determine whether there were any differences in the median values among the AFL, Rugby League, Rugby Union (XVs) and Rugby 7s players. For the two variables that met all assumptions of parametric statistics (breast bridge and breast height), a One-way ANOVA design was used to determine whether there were any differences in the mean values among the AFL, Rugby League, Rugby Union (XVs) and Rugby 7s players. Although multiple statistical tests were conducted, increasing the chance of incurring an error, no adjustment to the alpha level was deemed necessary given the exploratory nature of the study and the low cost associated with incurring an error (Sinclair et al. 2013). Differences in the median (Kruskal-Wallis) or means (ANOVA) between groups and all pairwise comparisons were therefore considered statistically significant at $p < 0.05$. All statistics were conducted in the Statistical Package for the Social Sciences (Version 23, IBM Statistics, Chicago, USA).

7.3 Results

7.3.1 Participant characteristics

One hundred and seventeen female contact football players consented to participate in the study. The cohort included 60 AFL players, 22 Rugby League players, 17 Rugby Union
(XVs) players and 18 Rugby 7s players. Eighteen percent of the participants were members of teams that competed in national or international competitions. Physical characteristics of the participants grouped by football code are presented in Table 15.

Table 15: Mean (± standard deviation) age, height, body mass and body fat percentage values for the participants, presented by contact football code.

<table>
<thead>
<tr>
<th></th>
<th>AFL (n = 60)</th>
<th>Rugby League (n = 22)</th>
<th>Rugby Union (n = 17)</th>
<th>Rugby 7s (n = 18)</th>
<th>All participants (n = 117)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>25.4 ± 5.9</td>
<td>25.7 ± 6.9</td>
<td>26.9 ± 5.7</td>
<td>21.6 ± 3.4</td>
<td>25.1 ± 5.9</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.3 ± 6.6</td>
<td>167.8 ± 6.6</td>
<td>167.8 ± 4.2</td>
<td>166.8 ± 5.4</td>
<td>167.9 ± 6.1</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>68.8 ± 11.2</td>
<td>79.8 ± 16.7</td>
<td>81.7 ± 18.4</td>
<td>68.8 ± 6.8</td>
<td>72.8 ± 14.1</td>
</tr>
<tr>
<td>Body fat percentage (%)</td>
<td>25.9 ± 7.9</td>
<td>30.3 ± 8.5</td>
<td>31.5 ± 8.0</td>
<td>25.5 ± 5.3</td>
<td>27.5 ± 8.0</td>
</tr>
</tbody>
</table>

a represents a statistically significant (p <0.05) difference in median between AFL and Rugby League
b represents a statistically significant (p <0.05) difference in median between AFL and Rugby Union
c represents a statistically significant (p <0.05) difference in median between AFL and Rugby 7s
d represents a statistically significant (p <0.05) difference in median between Rugby League and Rugby 7s
e represents a statistically significant (p <0.05) difference in median between Rugby Union and Rugby 7s

7.3.2 Breast size, breast position and torso size measurements

Normative data on the breast size, breast position and torso characteristics of the participants are presented in Figures 17, 18 and 19, respectively. Breast surface area, breast length and breast width significantly varied between the contact football codes (see Figure 17), but no significant differences were observed among the contact football codes with respect to the four breast position measurements (see Figure 18). Of the three torso size measurements, the UBCC and chest width of participants from Rugby 7s and AFL were both significantly smaller than participants from Rugby League or Rugby Union (see Figure 19).
Breast characteristics

Figure 17: Box plots depicting the median and interquartile range of the breast size measurements (A)–(F) by contact football code.

○ represents outliers and * represents extreme outliers

* indicates significant difference between contact football codes at $p < 0.05$
Breast characteristics

Figure 18: Box plots depicting the median and interquartile range of the breast position measurements (A)–(D) by contact football code.

◦ represents outliers
Breast characteristics

Figure 19: Box plots depicting the median and interquartile range of the torso size measurements (A)–(C) by contact football code.

- ○ represents outliers
- * indicates significant difference between contact football codes at $p < 0.05$

7.4 Discussion

Participant characteristics recorded in this study were consistent with mean height and body mass values that have been reported by previous studies of female AFL players (Black et al. 2017), Rugby League (forwards only; Jones et al. 2016), Rugby Union (forwards only; Suarez-Arrones et al. 2014) and Rugby 7s players (Clarke et al. 2014; Clarke et al. 2017; Suarez-Arrones et al. 2012). Female contact football players displayed a wide range of breast and torso characteristics that must be considered when designing any equipment to support or protect their breasts against injuries. Significant differences in the dimensions of the breasts and torso were also revealed amongst players from the various contact football codes. The implications of these findings in terms of designing sports bras and breast protective equipment are discussed below.
7.4.1 Normative data on breast size, breast position and torso size measurements

Contrary to the popular belief that female athletes typically have small breasts (Mason et al. 1999), the median breast volume reported in this study (342 ml) was consistent with the median breast volume for women of a similar age from the general population (363 ml) (Coltman et al. 2017b). The range of breast volumes and under-breast chest circumferences (UBCC) of the female contact football players reported in this study were within the range of the general female population. The majority were within the small-medium range of breast volumes and under-breast chest circumferences (UBCC) that have been reported for the general female population, which is also consistent with previous research of self-reported bra sizes of female contact football players (see Chapter 6, Section 6.3.1).

Although the ranges of breast volumes and UBCC measurements were smaller compared to the general female population, they were still broad (breast volumes of 85–1616 mL and UBCC 75–105 cm). It is therefore possible that the existing array of sports bra sizes (breast and torso dimension variations and combinations) does not accommodate such a broad range and, along with other factors such as insufficient knowledge of correct bra fit (McGhee et al. 2010a), this might have contributed to the high percentage of poor bra fit described in Chapter 6, Section 6.3.3. This is consistent with previous research of the general female population (Coltman et al. 2018b; McGhee and Steele 2010b), where a higher percentage of poor bra fit was associated with a larger breast size. The higher percentage of female contact football players who wore crop tops compared to previous studies of the general female population (Bowles et al. 2008; Coltman et al. 2018b) might also have had a positive impact on bra fit, because the less structured design of crop tops makes them easier to fit correctly compared to encapsulation sports bras.
Sports bras and breast protective equipment are close-fitting garments. In order for them to fit correctly, they must match the combined breast and torso dimensions of the wearer. The breast and torso characteristics of the female contact football players found in the current study could be used to assess the relative “fit loss” of current sports bras and breast protective equipment. That is, it provides evidence that could be used to determine how well current bra sizing practices yield products that match the dimensions of the population that sports bras and breast protective equipment are designed for. Such review of practice could improve the future fit and designs of these garments.

Sternal notch to nipple distance is widely used to classify ptosis or sagging of the breasts (Coltman et al. 2017a; Liu and Thomson 2011; Penn 1954; Smith et al. 1986; Steele et al. 2017; Westreich 1997). The smaller mean sternal notch to nipple distance recorded in this study (214 mm) was consistent with measurements representative of a pert breast (Liu and Thomson 2011; Penn 1954; Smith et al. 1986; Westreich 1997). This is not surprising given the relatively young age of participants, because level of breasts ptosis has been shown to increase with age (Brown et al. 1999; Coltman et al. 2018a). Breast shape and the location of the breasts on the torso have important implications for the design of any garment worn over the breasts, including sports bras and breast protective equipment, to ensure that the garment actually covers all of the breast tissue, accommodates the breast dimensions and that there is sufficient strap length. Although sports bras are worn directly over the naked breast, the limited external breast protective designs commercially available are worn external to a sports bra. Future breast protective garment designs could be incorporated into a sports bra or be designed to wear externally. However, breast location and shape measurements may differ when measured from a scan of the torso in the bare-breasted condition (as in the current study) compared to when measured from a scan of the torso while players wear a sports bra. Future research to
Breast characteristics

investigate breast protective equipment designs for female contact football players is therefore recommended to include both bare-breasts scans (for sports bra and within-sports bra protection) and scans when correctly fitted, standardised sports bras are worn (for breast protection designed to be worn external to a sports bra).

No published studies have reported data for the distance between the right and left breast at the narrowest point (breast bridge) or the distance between the lateral breast and the anterior axillary line (lateral breast position) in the general female population. These measurements, however, have important implications for how sports bras and breast protective equipment should be designed to cover the breasts and where other features, such as padding or cups, should be placed. The breast bridge and lateral breast position data recorded in this study highlight that female contact football players have an extensive range of breast positions. The distance between the right and left breast ranged from 2.7 to 45.6 mm, whereby smaller values indicate that a woman’s breasts are nearly touching at the midline and larger values represent breasts with considerable space between them (across the sternum). Similarly, a 10 cm range of values was associated with lateral breast position, such that some participants had breast tissue that was located beyond the anterior axillary line. It is unlikely that the breasts of these players are adequately protected if the shape and size of the padded area or moulded cup of sports bras or breast protective equipment does not extend far enough around the lateral torso. However, many contact football players also complained that existing breast protective equipment restricted the motion of their arms or was too hot, both concerns that could potentially be exacerbated by the addition of unnecessary lateral padding. Therefore, it is vital for designers to develop breast protective equipment that caters for a range of breast positions so that female contact football players are able to wear a garment that provides sufficient
protection to their breasts without restricting movement of their arms or adding unnecessary bulk.

The torso size of female contact football players is also important when designing any breast protective equipment that will encompass the trunk, such as the bra band or the posterior component of breast and chest padding. Most commercially available chest padding, however, has been designed for male players. The average UBCC recorded for female athletes in this study (82 cm) differed widely to average chest circumference measurements that have been reported for males (96–101 cm; Fink et al. 2003; Furnell et al. 2014). These data indicate that male chest padding would be unlikely to fit most female athletes due to differences in torso dimensions. It is also likely that the flat male chest pads available do not cater for the anteriorly protruding breasts characteristic of most female football players. Therefore, developing female-specific protective equipment that will accommodate a range of breast sizes and shapes and cater for the smaller torsos of women is crucial for contact football players.

7.4.2 Breast size, breast position and torso size measurements by contact football code

There were no significant differences in breast size or breast position amongst the different contact football codes, despite varied match demands that might influence body shape and therefore breast characteristics (Coutts et al. 2010; Cummins et al. 2013; Cunniffe et al. 2009; Gray and Jenkins 2010; Orchard and Seward 2009; Waldron et al. 2011; Wisbey et al. 2010). As these measurements are indicative of where protective features, such as padding, should be located on a garment in order to provide adequate coverage and protection to breast tissue, it is likely that a range of sizes in breast protective equipment will successfully cater for female contact football athletes, irrespective of code.
Several key differences in both breast shape and torso size, however, were also recorded between contact the football codes, which are likely to have implications for designing sports bras and breast protective equipment. Breast shape is largely influenced by breast surface area (Coltman et al. 2018a; Thomson et al. 2009), which was significantly lower in Rugby 7s players than in either Rugby League or Rugby Union players. The notion that female contact football players possess a range of breast shapes was also supported by the measures of breast length and breast width, which were significantly lower in Rugby 7s players (length) and in AFL and Rugby 7s players (width) compared to players from all other codes. However, breast volume did not significantly differ amongst these participants. Therefore, the smaller breast width and length are likely to represent different breast shapes, such as “round” breasts that are characteristically narrow (Coltman et al. 2018a), rather than overall smaller breasts in AFL and Rugby 7s players. As breast shape might affect the fit of sports bras and breast protective equipment, the varied breast shape and size data presented in this study indicate the range of dimensions that must be considered when designing breast support and protective equipment for female contact football players.

In terms of torso dimensions, the UBCC and chest width measurements for AFL and Rugby 7s players were significantly smaller than those recorded for Rugby League or Rugby Union players. These data suggest that AFL and Rugby 7s players, in addition to having a different breast shape, might also have smaller torsos than Rugby League or Rugby Union players, possibly related to their significantly lower body mass and body fat percentages. These measurements have important implications for the fit and design of sports bras and breast protective equipment, because any breast garment, including breast padding and sports bras, will need to fit snugly around the torso to remain fixed during matches. It is therefore recommended that designers include the option for players
to adjust any sports bra or breast protective equipment around the torso so that it will cater for the range of torso sizes observed across the contact football codes.

In addition to considering the breast and torso characteristics of players, it is imperative that designers and manufacturers of breast protective equipment consider the relevant rules and regulations governing the use of protective equipment within each of the contact football codes (see Table 16). For instance, World Rugby design guidelines for breast padding stipulate that semi-rigid cups “must” be used to provide additional protection to the area surrounding the nipples (World Rugby 2015). Regulations governing Rugby League, however, specifically prohibit anything of a “rigid nature” from being worn during a match (Australian Rugby League Commission 2019). Due to these differing regulations, code-specific breast protective equipment might be required. No published research, however, has documented the effectiveness of current breast protective equipment, with or without code-specific features. Therefore, it is recommended that further research evaluate the efficacy of breast protective equipment in order to determine the best evidence-based strategy for protecting the breasts. Based on the findings of such research, current regulations pertaining to breast protective equipment across the contact football codes might require review.

7.4.3 Limitations

Although this study was the first to provide normative data on the breast size, breast position and torso size of women who participate in the contact football codes, a limitation of this research was the relatively small sample size within several of the codes. Differences in breast and torso dimensions might also exist amongst player positions within the contact football codes, and this warrants further investigation. Despite most breast protective equipment being worn external to the sports bra, this study only included bare-breasted measurements of the breasts and torso. This study therefore provides a
Breast characteristics

strong basis for future research, which is encouraged to recruit a larger sample, explore between-player variations and take additional measurements of the breasts and torso while players wear their training or match bra.
<table>
<thead>
<tr>
<th>Football code (governing body)</th>
<th>Resource</th>
<th>Breast protective equipment regulations</th>
</tr>
</thead>
</table>
| AFL (Australian Football League Commission) | Laws of Australian Football, 2019 | **Law 9.1** (p.29): “Protective Equipment includes but is not limited to… shoulders pads… and any other item designated as such by the relevant Controlling Body.”
**Law 9.2** (p.29): “A Player shall not wear during a Match… any Protective Equipment (other than Protective Equipment approved by the Controlling Body) unless the field Umpire is satisfied that the item does not constitute a danger or increase the risk of injury to other Players competing in the Match.” |
| Rugby League (Australian Rugby League Commission) | Rugby League Laws of the Game International Level, 2019 edition | **Section 4C** (p.10): “Protective clothing may be worn provided it contains nothing of a rigid or dangerous nature.” |
| Rugby Union & Rugby 7s (World Rugby) | Regulation 12: Provisions Relating to Players’ Dress, Schedule 1 | **Section 7.1** (p.209): “Breast padding is specific to female players and should be designed and constructed to minimise discomfort for the wearer.”
**Section 7.2.1.2** (p.210): “Where cups are part of the garment, it is important that these must be of a semi-rigid material and that this is limited to the front area about the nipple... The cups shall not exceed a perpendicular 4mm thickness from the front surface at any point.”
**Section 7.2.2** (p.210): “Breast padding shall be so constructed that it is unlikely to cause any injury to the wearer or other players during play. There shall not be hard or sharp edges, seams, buckles or other items on the surface of the product that could harm the wearer or other players during normal use.”
**Section 7.3.2** (p.210): “Breast padding shall have an area which covers the soft tissue and the axillary tail. Outline dimensions of the area of coverage shall be based on the under bust girth measurement with brassiere cup size or bust girth measurement.” |
7.5 Conclusion

Normative data characterising the breast size, breast position and torso size of 117 women who participate in the contact football codes has been provided. These data highlight that the breast and torso characteristics of female contact football athletes differed in some respects to measurements reported for females in the general population and among the contact football codes. It is essential that designers and manufacturers of sports bras and breast protective equipment consider the specific breast and torso dimensions of female contact football players, and that garments are designed to accommodate the extensive range of breast and torso sizes and shapes. Improving the design of sports bras and breast protective equipment has the potential to increase the fit, comfort and efficacy of these garments, although further research is warranted to investigate this notion.
Chapter 8

Summary and recommendations

8.1 Summary

Despite the apparent vulnerability of the female breasts to pain and injury during a range of high-intensity or contact sports, breast pain and breast injury have only been investigated in athletes from a limited number of sports. It was therefore necessary to investigate the extent to which breast pain and breast injury affected a diverse cohort of female athletes and whether these issues were perceived to hinder sporting performance. This thesis aimed to systematically investigate breast pain and breast injury in elite female athletes and contact football players, which was necessary to inform future research and evidence-based recommendations for sports to manage breast pain and breast injury. To achieve this overall thesis aim, an exploratory study was conducted to investigate the occurrence, causes and perceived performance effects of breast pain (Part I) and breast injury (Part II) in elite female athletes. Based on the unique findings of Part II of this thesis, which revealed that contact breast injuries were experienced by a high percentage of athletes involved in contact sports but that very few of these athletes were utilising any breast injury prevention strategies, a second study was conducted to evaluate the current breast injury and breast injury prevention situation in female contact football players (Part III). Finally, the breasts and torsos of female contact football players were characterised in Part IV in order to inform the design of future breast protective equipment.

8.1.1 Part I: Breast pain in elite female athletes

In Chapter 2, 540 female athletes competing nationally or internationally across 49 different sports completed a custom-designed online survey that included questions about the occurrence, severity and perceived performance effects of cyclic mastalgia and
exercise-induced breast pain. The results of the survey revealed that 33% of the respondents reported mastalgia that was exacerbated by training or competition and 44% reported experiencing exercise-induced breast pain during training or competition. More importantly, a proportion of the respondents perceived that both mastalgia (20%) and exercise-induced breast pain (32%) negatively affected their sporting performance. The self-reported occurrence and severity of exercise-induced breast pain was also found to increase during sport-specific movements, such as jumping and running. These findings confirmed that mastalgia associated with the menstrual cycle and exercise-induced breast pain can be problematic for female athletes, even at an elite level of sport.

In order to assist coaches and medical professionals to better recognise and manage breast pain experienced by elite female athletes, a model was developed to determine whether basic self-reported data could be used to predict which athletes were likely to report exercise-induced breast pain (see Chapter 3). The model was based on a binomial logistic regression using age, breast size, BMI and sports bra use as the predictive factors, because these variables have each been linked to decreased breast support, greater breast motion or increased breast pain in previous research (Brown et al. 2014b; Coltman et al. 2017b; Coltman et al. 2017c; McGhee et al. 2010b). Although statistically significant, the model was found to be weak in its ability to correctly predict which athletes reported exercise-induced breast pain (correctly identified 66% of athletes). However, the results of the regression analysis revealed that for every 1-year increase in age, there was a significant 2.6% increase in the likelihood of an athlete reporting exercise-induced breast pain. Athletes with medium, large or hypertrophic sized breasts were also 5.5-times more likely to report experiencing exercise-induced breast pain than athletes with small breasts. These findings highlight the need for breast pain management strategies that specifically accommodate older athletes and those with larger
breasts, because these women are more likely to report experiencing exercise-induced breast pain and, as a result, may be more susceptible to negative performance effects as a consequence of this breast pain.

8.1.2 Part II: Breast injuries in elite female athletes

In Chapter 4, the occurrence, causes and perceived performance effects of breast injuries reported by 504 elite female athletes, who were competing nationally or internationally across 46 different sports, were directly surveyed. The results of this survey revealed that more than one in three athletes reported sustaining a breast injury and one in five of these athletes perceived that their breast injury negatively affected their sporting performance. The respondents also reported two main types of breast injuries: (i) contact breast injuries, caused by direct contact with another athlete, with sporting equipment or with the ground, and (ii) frictional breast injuries, caused by friction from a bra or uniform rubbing or chafing the skin of the breasts. Contact breast injuries were reported by a significantly higher percentage of athletes involved in contact or combat sports and by athletes with larger breasts or a higher BMI. Frictional breast injuries were reported by a significantly higher percentage of older athletes or those with larger breasts. Concerningly, less than 10% of participants who experienced breast injuries reported their injury to a coach or medical professional and only half of the respondents reported using any strategies to prevent breast injuries. Based on the high occurrence and negative performance effects of contact breast injuries reported by contact and combat athletes and the limited use of breast injury prevention strategies specifically reported by contact athletes, contact breast injuries sustained by female contact football players were then investigated in further detail, as described below.
8.1.3 Part III: Current breast injury and breast injury prevention situation

The occurrence, causes and perceived performance effects of contact breast injuries sustained by female football players; how these contact breast injuries varied among football codes, player positions and competition levels; and the awareness and perceptions of coaches and medical professionals about contact breast injuries were investigated in Chapter 5. This information was collected from two custom-designed surveys. The first survey, completed by 297 female Australian Football (AFL), Rugby League, Rugby Union (XVs) and Rugby 7s players, asked the respondents about their experience of breast injuries. Contact breast injuries were reported to have ever been experienced by 58% of the contact football players, 48% of whom perceived that their injury negatively affected their football performance. Injury occurrence was observed to vary across the contact football codes, such that a significantly higher proportion of Rugby Union (XVs) players reported sustaining breast injuries that were caused by contact with another player compared to AFL players. A significantly lower proportion of AFL players reported sustaining breast injuries caused by contact with the ground compared to players from all other codes. A higher proportion of AFL backs also reported sustaining breast injuries that were caused by contact with another player compared to AFL forwards or midfielders. These findings suggest that breast injury occurrence varies across football codes and player positions, although it is unknown whether the frequency or incidence of breast injury varies in a similar manner amongst female contact football players because only breast injuries ever experienced by players were investigated in this thesis.

The second survey, completed by 242 coaching and medical staff associated with female contact football teams, sought information about breast injury awareness and perceptions of these staff. Despite more than half of the player participants reporting that
they had ever experienced a contact breast injury, most of the coaches and medical professionals surveyed perceived that less than 5% of players had ever experienced a contact breast injury. Athletes, coaches and medical professionals therefore need to be educated about the potential for, and the effects of, contact breast injuries in contact football. Based on these findings, it was also necessary to evaluate what, if anything, female contact football players were doing to protect their breasts against contact breast injury.

In Chapter 6, the use of breast protective equipment during training and matches was investigated through a survey of 207 female AFL, Rugby League, Rugby Union (XVs) and Rugby 7s players. Only 17% of respondents reported using breast or chest padding, primarily because they did not know it existed or because they found it uncomfortable and ill-fitting. Of the limited number of athletes who did use padding, 66% perceived that it protected their breasts against contact injury. All participants wore some form of bra during training and matches, and about one-third of female contact football players perceived that their sports bra protected their breasts against contact injury. Of the female contact football players who completed the survey, 112 of the respondents also attended a testing session, during which the bra they typically wore to training or competition was assessed. The results of this bra assessment revealed that more than half of the participants were wearing an ill-fitting bra or a bra that did not completely cover their breast tissue, which was therefore unlikely to provide adequate protection against injury. The reported discomfort associated with breast padding and the observed ill-fit of sports bras in female contact football players might also discourage players from using this potentially effective injury prevention strategy. It was therefore necessary to characterise the breasts and torsos of female contact football players in order to provide normative data, which could then be used to improve the design of breast protective
equipment to better cater for the breasts of female contact football players across the codes.

### 8.1.4 Part IV: Breast and torso characteristics of female contact football players

In Chapter 7, 117 female AFL, Rugby League, Rugby Union (XVs) and Rugby 7s players attended a single testing session where a three-dimensional scan was taken of their breasts and torsos in order to quantify their breast size, breast position and torso size. Torso dimensions calculated for female contact football players differed substantially to those previously reported for men. Therefore, it is unlikely that male chest protective equipment, which is more widely available than female-specific protective equipment, will accommodate the breasts of female contact football players. Measurements of breast surface area, length and width, as well as under-bust chest circumference and chest width, also varied significantly amongst participants from the different female contact football codes. Most importantly, a wide range of breast and torso characteristics were observed for female contact football players, including a range of breast volumes, medial and lateral breast positions on the torso and chest circumferences. It is therefore essential that designers and manufacturers of breast protective equipment consider the specific breast and torso dimensions of female contact football players across all codes and that breast protective equipment is designed to accommodate the extensive range of breast and torso sizes and shapes. Evidence-based designs have the potential to improve the fit and comfort, as well as the overall effectiveness, of breast protective equipment for female contact football players.

### 8.2 Recommendations for future research

Based on the results of this thesis, the following recommendations are made to guide future research:
(i) Researchers should build upon the binomial logistic regression model investigated in Chapter 3 to develop a model that can predict which female athletes are likely to report experiencing exercise-induced breast pain. Such a model would enable coaches and medical professionals associated with female sports teams to identify players who could benefit from specific strategies to minimise their breast pain. Variables such as age, a direct measure of breast size (e.g. breast volume), a direct measure of body composition (e.g. body fat percentage), bra fit/breast support level and a valid measure of training volume should be explored in the new model.

(ii) Most female athletes do not report their breast injuries to coaches or medical professionals. Future research investigating breast injuries should therefore directly query athletes about these injuries and record “any physical complaint” of breast injury during training and competition until there is more evidence about whether breast injuries result in time-loss or necessitate medical attention. Injury reporting forms and sport-specific surveillance systems should also include a specific “breast/chest” injury category. These recommendations will ensure that contact breast injuries will not be systematically excluded in future sports injury research.

(iii) This thesis established that breast injuries do occur and can negatively affect the sporting performance of female contact football players, which provides justification for future researchers to devote the necessary resources to investigating breast injury incidence, as per the TIP framework. Injury surveillance studies should therefore be conducted across all of the contact football codes to determine the frequency of breast injury relative to hours of exposure (training and match play).
Based on the TIP framework, the results of this thesis can also be used to inform future research on breast injury risk and the specific mechanisms of breast injury in female contact football players (Phase Two). Specifically, it is necessary to investigate which players are most susceptible to breast injury and during which game plays these injuries are occurring. Knowledge of when and how players are sustaining breast injuries is crucial to develop evidence-based prevention strategies (Phase Three), which could ultimately reduce the occurrence and negative performance effects of contact breast injuries for these players.

In order to improve the fit and comfort of current breast protective equipment for female contact football players, manufacturers should use the normative breast and torso data presented in Chapter 7 to design garments that will specifically cater for this population. Breast protective equipment should include a range of sizes that will accommodate the variety of breast and torso shapes and sizes observed across the various contact football codes, as well as options for adjustability that will allow players to achieve proper fit. Future research is recommended to consider breast characteristics of female contact football players while wearing their training or match bra, as protective equipment is commonly worn external to a bra and breast location and shape can differ depending on breast support. It might also be necessary to investigate code-specific protective equipment that corresponds to the breasts of the players and adheres to the specific regulations for protective equipment within each of the contact football codes.

Following improvements to the fit and design of breast protective equipment, it is necessary to evaluate the effectiveness of these garments in preventing breast injuries during contact football. Specifically, future research should investigate whether breast protective equipment is able to reduce the occurrence or severity
of breast injuries and whether these garments have any effect on player performance.

(vii) In addition to breast protective equipment, it is recommended that other potential breast injury prevention strategies, such as modifications to technique, are scientifically investigated. Future studies of prevention strategies should also engage all stakeholders, including players, coaching staff, associated medical professionals and sporting organisation, to ensure that potential solutions are not only efficacious, but also positively perceived by those who will utilise the strategies and feasible for those who will implement the strategies.

(viii) Although the occurrence of breast injuries (Chapter 5), use of protective equipment (Chapter 6) and breast/torso characteristics (Chapter 7) of female contact football players were specifically explored in the latter chapters of this thesis, it is important to acknowledge that female athletes from a wide variety of sports reported experiencing frictional and contact breast injuries in Chapter 4. Therefore, further research is encouraged to investigate additional cohorts of female athletes to determine whether other sports also require prevention strategies for breast injuries, which might include breast protective equipment that is designed specifically for their sport.

8.3 Recommendations for sports to manage breast pain and breast injury

Based on the results of this thesis, the following evidence-based recommendations are made for sports to manage breast pain and breast injury:

(i) Female athletes across all sports, especially older athletes and those with larger breasts, should receive education on strategies to reduce mastalgia and exercise-induced breast pain during training and competition. One simple strategy that has been shown to effectively relieve up to 85% of breast pain symptoms is wearing
a properly fitted, high support bra (Hadi 2000). This is because a well-designed and fitted sports bra can reduce breast motion and, in turn, reduce breast pain compared to wearing inadequate breast support. Evidence-based educational resources are available and should be used to educate female athletes on the importance of adequate breast support and how to select and correctly fit a sports bra that caters for the movements specific to their sport (McGhee et al. 2008).

(ii) It is vital that female athletes, particularly female contact football players, are educated about the potential for breast injuries and how these injuries can negatively affect their football performance. Encouraging accurate reporting and recording of breast injuries will enable future sport-specific surveillance systems to collect valid breast injury data, which is essential for the future development and implementation of breast injury prevention strategies. It will also ensure that, where necessary, female athletes receive appropriate treatment for their breast injuries.

(iii) It is also essential to “normalise the conversation” about breast injuries amongst coaches and medical professionals working with female contact football players. Many staff expressed that they were unsure of how to talk to their players about breast injuries, and therefore it is recommended that staff receive education about breast injury risk and potential prevention strategies, as well as training on how to create an open dialogue with their players about breast injury. An example of an evidence-based resource that could be used to educate female contact football players and their coaches about breast injuries is included in Appendix E.
REFERENCES


Ball K. Use of weighted balls for improving kicking for distance. *Proceedings of the 6th World Congress on Science and Football, Antalya, Turkey, 15-20 Jan 2007.*


Malcom NL. “Shaking it off” and “toughing it out” socialization to pain and injury in girls’ softball. *Journal of contemporary ethnography*. 2006;35(5):495-525.


McGhee DE, Steele JR, Munro BJ. Sports Bra Fitness. Wollongong, NSW: Breast Research Australia (BRA), Biomechanics Research Laboratory, University of Wollongong. 2008.


Pluim BM, Fuller CW, Batt ME, Chase L, Hainline B, Miller S, Montalvan B, Renström P, Stroia KA, Weber K. Consensus statement on epidemiological...


Shivitz NL. Adaptation of vertical ground reaction force due to changes in breast support in running (Masters thesis). Oregon State University, Corvallis, USA. 2001.


References


White J, Scurr J, Hedger W. Three-dimensional breast displacement and breast comfort in small and large-breasted women during jumping and agility tasks.


## Appendix A

### International bra sizing

#### International bra band sizes

<table>
<thead>
<tr>
<th>Australia</th>
<th>USA</th>
<th>UK</th>
<th>France</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>28</td>
<td>28</td>
<td>75</td>
<td>60</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
<td>30</td>
<td>80</td>
<td>65</td>
</tr>
<tr>
<td>10</td>
<td>32</td>
<td>32</td>
<td>85</td>
<td>70</td>
</tr>
<tr>
<td>12</td>
<td>34</td>
<td>34</td>
<td>90</td>
<td>75</td>
</tr>
<tr>
<td>14</td>
<td>36</td>
<td>36</td>
<td>95</td>
<td>80</td>
</tr>
<tr>
<td>16</td>
<td>38</td>
<td>38</td>
<td>100</td>
<td>85</td>
</tr>
<tr>
<td>18</td>
<td>40</td>
<td>40</td>
<td>105</td>
<td>90</td>
</tr>
<tr>
<td>20</td>
<td>42</td>
<td>42</td>
<td>110</td>
<td>95</td>
</tr>
</tbody>
</table>

#### International bra cup sizes

<table>
<thead>
<tr>
<th>Australia</th>
<th>USA</th>
<th>UK</th>
<th>France</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>DD</td>
<td>DD or E</td>
<td>DD</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>E</td>
<td>DDD or F</td>
<td>E</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>G</td>
<td>F</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>FF</td>
<td>H</td>
<td>FF</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>G</td>
<td>I</td>
<td>G</td>
<td>J</td>
<td>J</td>
</tr>
<tr>
<td>GG</td>
<td>J</td>
<td>GG</td>
<td>K</td>
<td>K</td>
</tr>
<tr>
<td>H</td>
<td>K</td>
<td>H</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>HH</td>
<td>L</td>
<td>HH</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>J</td>
<td>M</td>
<td>J</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>
Appendix B

Breast pain and breast injury survey

Data from the following survey were presented in Chapters 2–4.

Breast pain, breast injury & bra use in high-performance female athletes

This survey is about breast-related issues and bra wearing habits of high-performance female athletes. To complete this survey, you must be:

- 18+ years of age
- **competing at a national or international level** in sport (e.g. National Championships, World Championships, Olympics, etc.)

It will take ~10 minutes to complete and will be fully confidential. The survey can also be completed online at [bit.ly/2g2BOPm](http://bit.ly/2g2BOPm).

The survey is being conducted as part of a research thesis by Brooke Brisbine, University of Wollongong and Movement Science Discipline, Australian Institute of Sport. If you have any questions about the survey, please contact Brooke Brisbine at brooke.brisbine@ausport.gov.au.

This study has been approved by the University of Wollongong Human Research Ethics Committee (HREC2017/009) and has received reciprocal ethics approval from the Australian Institute of Sport (20170610). For more information about the study, please refer to the Participant Information Sheet.
Appendix B: Breast pain and breast injury survey

I. About you

In this section, we want to learn about you and your involvement in sport.

Q1 Please write your date of birth: ____/____/_______

Q2 Please write your height in cm: _________

Q3 Please write your weight in kg: _________

Q4 Please write the following information about your primary competitive sport.

Your primary sport: __________________________

Your event/position: _________________________

Q5 At what level of sport are you currently competing?

☑ National competitions (e.g. National Championships)

☑ International competitions (e.g. World Championships/Olympics)

☑ Other: __________________________

Q6 During your primary competitive season, on average how many hours a week do you spend training for and competing in your primary sport?

Training hours _________

Competition hours _________
II. About your bra

In this section, we want to learn about the bras you wear during sport and what you like/dislike about them.

Q7 What is your bra size? If you do not know your exact bra size, please estimate to the best of your ability. Write the band size & cup size (e.g. 8B, 32DD). ______________

Q8 Have you ever had your bra size measured or been professionally fitted into a bra?
- Yes, I have had my bra size measured or been professionally fitted into a bra in the last year.
- Yes, I had my bra size measured or was professionally fitted into a bra more than a year ago.
- No, I have never had my bra size measured or been professionally fitted into a bra.

Q9 Have any of the following factors ever influenced your sports bra selection?

<table>
<thead>
<tr>
<th>Factor</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform (e.g. I can only wear racerback bras because of my uniform, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sponsorship by specific brands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price of sports bras</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of my size (e.g. It's hard to find a bra that fits correctly)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Q10 Have any factors other than those listed above ever influenced your sports bra selection?

Q11 How do you typically get your sports bras? Select all that apply.
- I am given sports bras as part of my personal sponsorship
- I am given sports bras as part of my NSO/ASC sponsorship
- I am given sports bras as part of my team uniform
- I purchase my sports bras from a specialty bra shop
- I purchase my sports bras from a department/sports store
- I purchase my sports bras online
### Q12 How frequently do you wear the following bra styles during training or competition?

<table>
<thead>
<tr>
<th>Bra Style</th>
<th>Always</th>
<th>Most of the time</th>
<th>Some of the time</th>
<th>A little of the time</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sports bra with cups</strong> (either with or without underwire)</td>
<td><img src="image" alt="Sports Bra" /></td>
<td><img src="image" alt="Always" /></td>
<td><img src="image" alt="Most of the time" /></td>
<td><img src="image" alt="Some of the time" /></td>
<td><img src="image" alt="A little of the time" /></td>
</tr>
<tr>
<td><strong>Hybrid sports bra</strong> (distinct cups with compression, no underwire)</td>
<td><img src="image" alt="Hybrid Sports Bra" /></td>
<td><img src="image" alt="Always" /></td>
<td><img src="image" alt="Most of the time" /></td>
<td><img src="image" alt="Some of the time" /></td>
<td><img src="image" alt="A little of the time" /></td>
</tr>
<tr>
<td><strong>Compression sports bra/crop top</strong> (without distinct cups)</td>
<td><img src="image" alt="Compression Sports Bra" /></td>
<td><img src="image" alt="Always" /></td>
<td><img src="image" alt="Most of the time" /></td>
<td><img src="image" alt="Some of the time" /></td>
<td><img src="image" alt="A little of the time" /></td>
</tr>
<tr>
<td><strong>Protective bra/chest guard</strong> (bra with hard plastic cups)</td>
<td><img src="image" alt="Protective Bra" /></td>
<td><img src="image" alt="Always" /></td>
<td><img src="image" alt="Most of the time" /></td>
<td><img src="image" alt="Some of the time" /></td>
<td><img src="image" alt="A little of the time" /></td>
</tr>
<tr>
<td><strong>Everyday bra</strong> (underwire bra with or without padding)</td>
<td><img src="image" alt="Everyday Bra" /></td>
<td><img src="image" alt="Always" /></td>
<td><img src="image" alt="Most of the time" /></td>
<td><img src="image" alt="Some of the time" /></td>
<td><img src="image" alt="A little of the time" /></td>
</tr>
<tr>
<td><strong>Bralette</strong> (without moulded cups or underwire)</td>
<td><img src="image" alt="Bralette" /></td>
<td><img src="image" alt="Always" /></td>
<td><img src="image" alt="Most of the time" /></td>
<td><img src="image" alt="Some of the time" /></td>
<td><img src="image" alt="A little of the time" /></td>
</tr>
</tbody>
</table>
Appendix B: Breast pain and breast injury survey

Breast pain, breast injury & bra use in high-performance female athletes

Q13 Do you ever wear multiple bras at a time during training or competition?
☐ Yes
☐ No

Q14 If you sometimes wear multiple bras at a time during training or competition, please describe what styles of bras you wear and why. (e.g. "I often wear an everyday bra under my crop top for extra support/for extra padding to protect my breasts").

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

Q15 How often do you wear a sports bra (either a sports bra with cups or a crop top style sports bra):

<table>
<thead>
<tr>
<th></th>
<th>Always</th>
<th>Most of the time</th>
<th>Some of the time</th>
<th>A little of the time</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>during training?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>during competition?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

If you answered “never” to both parts of this question, skip to Q22 in section III: Your breast pain.

Q16 Answer the following questions about the sports bra that you most often wear. How satisfied are you with:

<table>
<thead>
<tr>
<th></th>
<th>Very satisfied</th>
<th>Somewhat satisfied</th>
<th>Neither satisfied nor dissatisfied</th>
<th>Somewhat dissatisfied</th>
<th>Very dissatisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>the comfort of your sports bra?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>the fit of your sports bra?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>the support provided by your sports bra?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>the look of your sports bra?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
Appendix B: Breast pain and breast injury survey

Breast pain, breast injury & bra use in high-performance female athletes

Q17 What are the **best features** of your current sports bra? Select all that apply.
- Supports my breasts/minimises breast bounce
- Compresses my breasts
- Fits well
- Fully covers my breasts
- Hides my nipples
- Comfortable to wear
- Comfortable straps
- I like the strap position
- Offers multiple strap positions
- I like the material
- Breathable material/not hot to wear
- Dries quickly
- Moulded cups
- Has underwire
- Doesn't have underwire
- Easy to put on/take off
- I like how it looks (e.g. style/colour)
- Other(s): _____________________________

Q18 What are the **worst features** of your current sports bra? Select all that apply.
- Doesn't support my breasts/too much breast bounce
- Doesn't compress my breasts
- Doesn't fit well
- Not enough breast coverage
- Nipples visible through bra
- Uncomfortable to wear
- Straps dig into shoulders
- Straps slip off shoulders
- I don't like the strap position
- I don't like the material
- Not breathable/hot to wear
- Doesn't dry quickly
- Feels like I can't breathe
- Underwire digs into ribs
- Seams are uncomfortable
- Too difficult to put on/take off
- I don't like how it looks
- Other(s): _____________________________

6
Breast pain, breast injury & bra use in high-performance female athletes

Q19 Thinking about your "ideal sports bra", how do you feel about the following **sports bra design features**?

<table>
<thead>
<tr>
<th>Feature</th>
<th>Like</th>
<th>I don't know</th>
<th>Dislike</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical straps</td>
<td>🌟</td>
<td>🌟</td>
<td>🌟</td>
</tr>
<tr>
<td>Crossback straps</td>
<td></td>
<td>🌟</td>
<td>🌟</td>
</tr>
<tr>
<td>Racerback straps</td>
<td></td>
<td>🌟</td>
<td>🌟</td>
</tr>
<tr>
<td>Multiple straps</td>
<td></td>
<td>🌟</td>
<td>🌟</td>
</tr>
<tr>
<td>Thin straps</td>
<td></td>
<td>🌟</td>
<td>🌟</td>
</tr>
<tr>
<td>Wide straps</td>
<td></td>
<td>🌟</td>
<td>🌟</td>
</tr>
<tr>
<td>Clasp at the back</td>
<td>🌟</td>
<td>🌟</td>
<td>🌟</td>
</tr>
</tbody>
</table>
Appendix B: Breast pain and breast injury survey

### Breast pain, breast injury & bra use in high-performance female athletes

<table>
<thead>
<tr>
<th>Bra Type</th>
<th>Like</th>
<th>I don't know</th>
<th>Dislike</th>
</tr>
</thead>
<tbody>
<tr>
<td>Padding</td>
<td>🌵</td>
<td>🌵</td>
<td>🌵</td>
</tr>
<tr>
<td>Push-up</td>
<td>🌵</td>
<td>🌵</td>
<td>🌵</td>
</tr>
<tr>
<td>Underwire</td>
<td>🌵</td>
<td>🌵</td>
<td>🌵</td>
</tr>
<tr>
<td>Moulded cups</td>
<td>🌵</td>
<td>🌵</td>
<td>🌵</td>
</tr>
<tr>
<td>Compression</td>
<td>🌵</td>
<td>🌵</td>
<td>🌵</td>
</tr>
<tr>
<td>Full coverage</td>
<td>🌵</td>
<td>🌵</td>
<td>🌵</td>
</tr>
</tbody>
</table>

**Q20** Do you notice a **difference in breast movement** when wearing a sports bra (either a sports bra with cups or a crop top style sports bra) compared to wearing a non-sports bra?

- 🌵 More breast movement wearing a non-sports bra
- 🌵 No difference in breast movement
- 🌵 More breast movement wearing a sports bra
Breast pain, breast injury & bra use in high-performance female athletes

Q21 Do you ever feel embarrassed or self-conscious of your breast movement during training or competition?
- Yes, I feel embarrassed or self-conscious of my breast movement even when I am wearing my sports bra.
- Yes, I feel embarrassed or self-conscious of my breast movement when I am not wearing my sports bra.
- No, I never feel embarrassed or self-conscious of my breast movement.
III. Your breast pain

_In this section, we want to learn about any breast pain that you experience._

Q22 When do you experience **mastalgia** (sore breasts that are related to your menstrual cycle and not caused by exercise)?
- Always
- Around the time of my period
- Never

If you answered “never” to this question, skip to Q25.

Q23 Is your **mastalgia typically worsened by breast movement** during training or competition?
- Yes
- No

Q24 Do you feel like your mastalgia **negatively impacts your performance** in training or competition?
- Yes
- No

Q25 How frequently do you experience **exercise-induced breast pain** during training or competition (breast pain that is caused by excessive breast motion and usually starts and stops with activity)?
- Always
- Most of the time
- Some of the time
- A little of the time
- Never

If you answered “never” to this question, skip to Q32 in section IV: Your breast injuries.

Q26 How severe is the **exercise-induced breast pain** that you experience during training or competition?
- Very severe
- Severe
- Moderate
- Mild
- Not severe

Q27 Do you notice a **difference in breast pain** when wearing a sports bra (either a sports bra _with cups_ or a _crop top style sports bra_) compared to wearing a non-sports bra?
- More breast pain wearing a non-sports bra
- No difference in breast pain
- More breast pain wearing a sports bra
Appendix B: Breast pain and breast injury survey

Breast pain, breast injury & bra use in high-performance female athletes

Q28 Please indicate whether you agree or disagree with the following statements about your exercise-induced breast pain.

<table>
<thead>
<tr>
<th></th>
<th>Agree</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>My breast pain negatively impacts my ability to train.</td>
<td>☑</td>
<td>☑️</td>
</tr>
<tr>
<td>My breast pain negatively impacts my performance in competition.</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>My breast pain limits my participation in physical activities outside my sport.</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>I have considered a surgical breast reduction because of my breast pain.</td>
<td>☑️</td>
<td>☑️</td>
</tr>
</tbody>
</table>

Q29 Please identify which of the following activities cause exercise-induced breast pain for you.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Very severe breast pain</th>
<th>Severe breast pain</th>
<th>Moderate breast pain</th>
<th>Mild breast pain</th>
<th>No breast pain</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>Jogging</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>Running</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>Jumping</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>Landing from a jump/dismount</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>Throwing</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>Catching</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>Swinging a bat/racket/club</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>Kicking a ball</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
</tbody>
</table>

Q30 Are there any other sport-specific activities/movements not listed above that cause exercise-induced breast pain for you?

<table>
<thead>
<tr>
<th>Activity</th>
<th>Very severe breast pain</th>
<th>Severe breast pain</th>
<th>Moderate breast pain</th>
<th>Mild breast pain</th>
<th>No breast pain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
</tbody>
</table>
Appendix B: Breast pain and breast injury survey

Breast pain, breast injury & bra use in high-performance female athletes

AIS

Q31 What strategies do you personally use to reduce your exercise-induced breast pain? Select all that apply.
- Wear a sports bra
- Wear multiple bras at a time
- Strap my breasts to my chest using tape or bandages
- Buband™ or other breast compression band
- Modify my movements to limit breast motion
- Limit activities that are particularly painful
- Take pain medication
- I do not use any strategies to reduce my breast pain
- Other(s): ____________________
IV. Your breast injuries

In this last section, we are interested in learning about any breast injuries that you may have sustained during training or competition.

Q32 Have you ever had a breast injury during training or competition (e.g. a bruise to your breast from a direct blow, a cut from a piece of sporting equipment, a scrape, chafing of the nipples, etc.)?  
☐ Yes  
☐ No

If you have never had a breast injury, skip to the end of the survey.

Q33 Have any of the following factors ever contributed to a breast injury for you? Select all that apply.

☐ Direct blow from another athlete (e.g. elbowed/kicked in the chest)
☐ Direct blow from sporting equipment (e.g. soccer ball, hockey stick, etc.)
☐ Direct contact with a surface (e.g. falling onto chest)
☐ Contact from my sports bra/uniform (e.g. chafing of nipples, cut from underwire, etc.)

Q34 What strategies do you personally use to prevent breast injury during training or competition? Select all that apply.

☐ Wear a padded sports bra
☐ Wear a protective bra with hard cups
☐ Strap my breasts to my chest using tape or bandages
☐ Modify my movements to prevent breast injury
☐ Limit activities that might cause breast injury
☐ Protect my breasts with my hands during sport
☐ I do not use any strategies to prevent breast injury
☐ Other(s): ____________________________

Q35 In the last year, approximately how many breast injuries have you had? ___________

Q36 Which best describes the cause of the most severe breast injury you have ever had? Select one response.

☐ Direct blow from another athlete (e.g. elbowed/kicked in the chest)
☐ Direct contact with a surface (e.g. falling onto chest)
☐ Contact from my sports bra/uniform (e.g. chafing of nipples, cut from underwire, etc.)

Q37 Please describe your most severe breast injury in more detail.
• what type of injury it was (e.g. bruise, cut, nipple chafing, etc.)
• how the injury happened (e.g. hit by a ball, kicked by another player, etc.)
• pain at the time of injury (e.g. mild vs. severe)
• how long the injury took to heal
Breast pain, breast injury & bra use in high-performance female athletes

Appendix B: Breast pain and breast injury survey

Q38 Did your most severe breast injury affect your performance in training or competition?

☐ Yes
☒ No

Q39 If your most severe breast injury affected your performance in training or competition, please describe how (e.g. "I missed 3 days of training/I had to avoid specific activities due to my injury").
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

Q40 Did you consult anyone about your breast injury? Select all that apply.

☐ Parent
☐ Team mate
☐ Team coach
☐ GP (general doctor)
☐ Physiotherapist
☐ Sport scientist (e.g. biomechanist)
☐ I did not seek advice about the injury
☐ Other(s): ______________________________

Q41 Please describe the advice or treatment that you received for your breast injury.
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

Thank you for completing this survey!

Anything else to add about your sports bras, your breasts or your athletic performance?
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

14
Appendix C

Contact breast injury survey

Data from the following survey were presented in Chapters 5 and 6.

Breast Injury Questionnaire

This questionnaire is part of the study “Breast injuries incurred by female AFL, Rugby League and Rugby Union players: Recommendations for management and prevention” being conducted by AIS PhD Scholar Brooke Brisbine, who is based at the University of Wollongong. For more information, please refer to the Participant Information Sheet or contact the researcher at Brooke.Brisbine@ausport.gov.au.

It should take ~ 5 minutes to complete the following questions. Please provide as much details as possible.

1. What football code do you currently play? If you play more than 1 football code, circle your main code and answer all questions about that code.
   - AFL
   - Rugby League
   - Rugby 7’s
   - Rugby XV’s

2. Please circle or write the following information about your sport:
   - Your position: forward middle back
   - Your main position: _______________________
   - Your team: _______________________
   - Competitive level: regional state national international
   - Number of seasons: _______

3. About how many hours a week do you spend training during the season?
   - Contact training (i.e. team training): _______ hours per week
   - Non-contact training (i.e. gym): _______ hours per week

4. When is your birthday? _____/____/_______

5. What bra size do you most commonly wear? Circle a band size and a cup size.
   - AUS band size: 6 8 10 12 14 16 18 20 other: _______
   - OR
   - US band size: 28 30 32 34 36 38 40 42 other: _______
   - Cup size: A B C D DD E F G H I J K other: _______

6. Please rate your sports bra on the following Circle your answers.
   - Excellent Good Average Poor Terrible
   - Fit: 1 2 3 4 5
   - Support: 1 2 3 4 5
   - Comfort: 1 2 3 4 5
   - Protection: 1 2 3 4 5
7. How often do you wear the following bra styles during training or competition? Please answer for all bra types.

<table>
<thead>
<tr>
<th>Bra Style</th>
<th>Always</th>
<th>Sometimes</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sports bra with cups (cups, with or without underwire)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hybrid sports bra (distinct cups, compression over the top)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop top (compressive, without cups)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Everyday/ T-shirt bra (underwire bra with cups)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bralette (without cups or underwire)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. Do you ever wear multiple bras at once? (Circle one.)

Yes  No
Appendix C: Contact breast injury survey

Breast Injury Questionnaire

9. Have you ever had a breast injury (bruise, soft tissue damage, etc.) caused by direct contact or a direct blow from any of the following? Tick ☑ all that apply and give example.
   - Another athlete (e.g. elbowed in chest)
   - Sporting equipment (e.g. hit by ball)
   - A surface (e.g. falling onto chest)
   - None of these (if you have NEVER had a bruise or tissue damage to your breast, skip to the end of the questionnaire)

10. Do you feel that breast injuries affect your athletic performance? Tick ☑ all that apply.
   - Yes, I am distracted by the pain from a breast injury
   - Yes, I am less likely to dive or tackle when I have a breast injury
   - Yes, I am hesitant to dive or tackle because I might get a breast injury
   - Yes, I am unable to run comfortably when I have a breast injury
   - Yes, I am less confident when I have a breast injury
   - Yes, other: ____________________________
   - No, breast injuries do not affect my performance in any way

11. Approximately how frequently do you experience breast injuries? Circle one.
    - Every match
    - Most matches
    - Some matches
    - Very few matches
    - Almost no matches

12. Do you ever report your breast injuries to anyone? Tick ☑ all that apply.
    - Partner or family member
    - Team mate
    - Coach
    - Doctor
    - Physiotherapist
    - Other ____________________________
    - I did not report my breast injuries (skip to Question 14)

    Why not? ____________________________
Appendix C: Contact breast injury survey

Breast Injury Questionnaire

13. How did this person respond when you reported the injury? Tick ☐ all that apply and explain.
   - Recommended that I not engage in contact training, For how long: __________________
   - Recommended that I not play, For how long: __________________
   - Recommended that I report the injury to someone else, To whom: __________________
   - Recommended a specific treatment, What: __________________
   - Recommended that I “just deal with it”
   - Other recommendation: __________________

14. Do you use any strategies to prevent breast injuries? Tick ☐ all that apply and write brand/type.
   - Shoulder pads with chest pads: __________________
   - Chest pads: __________________
   - Bra with padding: __________________
   - Other: __________________
   - I don’t use any breast protection strategies (skip to Question 16)

15. If you do wear protective equipment for your breasts, do you find it effective? Yes ☐ No ☐
    If “No”, explain: __________________

16. If you do not wear protective equipment for your breasts, why not? Tick ☐ all that apply.
   - Uncomfortable
   - Too hot/ not breathable
   - Restrictive to my upper body/ arms
   - Not permitted to use it in my sport
   - It is not effective in preventing injury
   - Doesn’t fit my torso/breast shape
   - I didn’t know it existed
   - Only available for men/ don’t want to wear men’s padding
   - Other: __________________

17. Do you have any recommendations for the design of new breast protective equipment or ideas for how we could better prevent breast injuries in your sport?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Thank you for taking the time to complete this survey. We really appreciate your responses!
Appendix D

Staff survey

Data from the following survey were presented in Chapter 5.

Appendix D: Staff survey

Breast Injury Questionnaire — Coaching & Medical Staff

This questionnaire is part of the study “Breast injuries incurred by female AFL, Rugby League and Rugby Union players: Recommendations for management and prevention” being conducted by AIS PhD Scholar Brooke Brisbine, who is based at the University of Wollongong. For more information, please refer to the Participant Information Sheet or contact the researcher at Brooke.Brisbine@ausport.gov.au. It should take ~1 minute to answer the following questions.

1. With which football code are you currently involved? Circle one.
   - AFL
   - Rugby 7’s
   - XV’s
   - Rugby League

2. What is your role?
   - Coach
   - Other athletic staff
   - Doctor
   - Physio
   - Other medical staff
   - Other: ______________________

3. Do you believe that soft tissue injuries to the breast (bruising, etc.) are a problem for female football players? Circle your answer.
   - YES
   - NO

4. In your experience, approximately what percentage of your female football players have sustained soft tissue breast injuries?
   *Online survey included drop-down menu with options 0%, 5%, 10%, 15% … 80%, 85%, 90%, 100%

5. Do you believe that soft tissue breast injuries have the potential to negatively affect a female player’s football performance?
   - YES
   - NO

6. Have you ever treated or provided treatment advice for a soft tissue breast injury suffered by a female football player?
   - YES
   - NO

7. Do you think that female AFL/Rugby players should wear protective equipment on their breasts/chests to prevent against soft tissue breast injuries?
   - YES
   - NO

8. Do you have any comments about the design of breast protective equipment or about breast injuries in female football?

_______________________________________________________________________________________
_______________________________________________________________________________________
_______________________________________________________________________________________

Thank you for taking the time to complete the survey. We really appreciate your responses.
Appendix E

Breast injury fact sheet

Breast injuries in contact football
What players and coaches need to know

What are breast injuries? While playing any of the contact football codes, women can experience contact injuries to their breast. These breast injuries, such as haematomas and contusions (i.e. bruising), are usually caused by a direct blow to the breast by another player, the ball or the ground. Contact breast injuries typically occur during activities such as tackling, catching a ball, while in rucks and other contact situations.

Are breast injuries serious? Although breast injuries are not usually severe enough to remove a player from a match, they can negatively affect sporting performance. It is therefore important to report breast injuries so that coaches and medical staff are aware of the problem, the injury can be treated (if needed) and appropriate prevention strategies can be implemented.

A recent study by Breast Research Australia, University of Wollongong and the Australian Institute of Sport found that over half of contact football players had experienced a breast injury during training and matches. Players also reported that breast injuries reduced their confidence, altered the way they ran or otherwise negatively affected their performance due to pain.

Coaches and medical staff were largely unaware players were suffering these breast injuries or that the injuries were affecting players’ performances. Given the sensitive nature of breast injuries, it is necessary for staff to encourage players to report these issues by normalising conversations about breast injury within the team.

- 58% of contact football players reported experiencing a breast injury
- 48% of players perceived negative performance effects of their breast injury
- Breast injuries were caused by contact with another player, the ball or the ground
- 90% of players did not report their breast injury to coaches or medical staff
- Only 17% of players used strategies to prevent breast injuries

Data presented in this fact sheet were collected by Brooke Brisbine, Breast pain and breast injury in female athletes, PhD Thesis, Biomechanics Research Laboratory, University of Wollongong, NSW, Australia.